11-16-2021

QUICK - RELEASE END EFFECTOR TOOL INTERFACE

Shane Farritor

Thomas Frederick

US011173617B2

(12) **United States Patent**
Farritor et al.

(10) **Patent No.: US 11,173,617 B2**
(45) **Date of Patent: Nov. 16, 2021**

(54) **QUICK-RELEASE END EFFECTOR TOOL INTERFACE**

(71) Applicant: **Board of Regents of the University of Nebraska**, Lincoln, NE (US)

(72) Inventors: **Shane Farritor**, Lincoln, NE (US); **Thomas Frederick**, Lincoln, NE (US)

(73) Assignee: **BOARD OF REGENTS OF THE UNIVERSITY OF NEBRASKA**, Lincoln, NE (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1088 days.

(21) Appl. No.: **15/687,113**

(22) Filed: **Aug. 25, 2017**

(65) **Prior Publication Data**

US 2018/0056527 A1 Mar. 1, 2018

Related U.S. Application Data

(60) Provisional application No. 62/379,344, filed on Aug. 25, 2016.

(51) **Int. Cl.**

A61B 34/30	(2016.01)
B25J 19/00	(2006.01)
B25J 15/04	(2006.01)
A61B 34/00	(2016.01)
A61B 17/00	(2006.01)
H01R 13/00	(2006.01)
H01R 13/625	(2006.01)

(Continued)

(52) **U.S. Cl.**
CPC ***B25J 19/0029*** (2013.01); ***A61B 17/00234*** (2013.01); ***A61B 34/30*** (2016.02); ***A61B 34/70*** (2016.02); ***B25J 15/0408*** (2013.01); ***H01R 13/005*** (2013.01); ***H01R 13/625*** (2013.01); ***H01R 24/20*** (2013.01); *A61B 2017/00477* (2013.01); *A61B 2017/2931* (2013.01); *H01R 13/24* (2013.01); *H01R 24/86* (2013.01); *H01R 2107/00* (2013.01); *H01R 2201/12* (2013.01)

(58) **Field of Classification Search**
CPC A61B 34/30; H01R 13/005; H01R 13/625
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,870,264 A 3/1975 Robinson
3,989,952 A 11/1976 Timberlake et al.
(Continued)

FOREIGN PATENT DOCUMENTS

CN 102821918 12/2012
DE 102010040405 3/2012
(Continued)

OTHER PUBLICATIONS

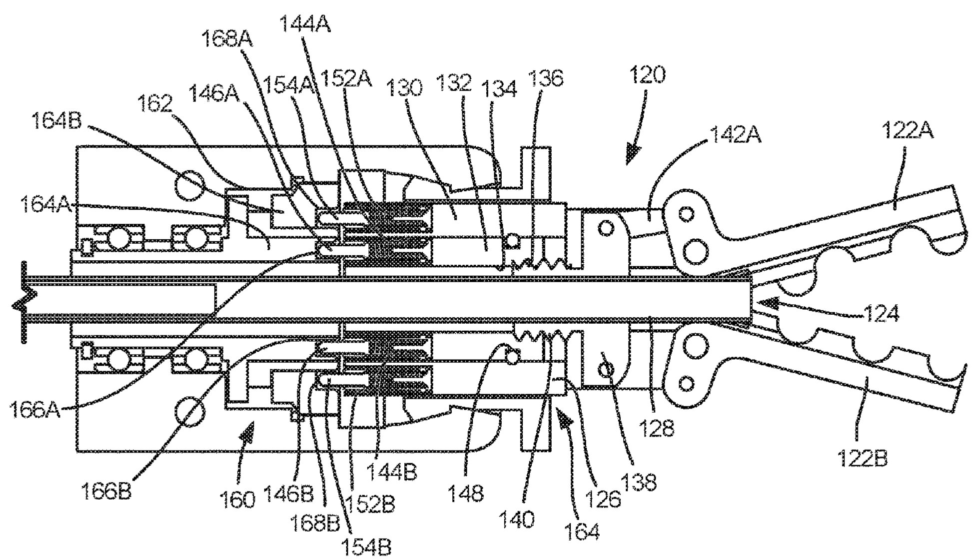
Franzino, "The Laprotek Surgical System and the Next Generation of Robotics," Surg Clin North Am, 2003 83(6): 1317-1320.
(Continued)

Primary Examiner — Daniel J Wiley
(74) *Attorney, Agent, or Firm* — Fredrikson & Byron, P.A.; Sean Solberg

(57) **ABSTRACT**

The various embodiments herein relate to a coupling apparatus for a medical device having a coupler body, a cavity defined in the coupler body, a rotatable drive component disposed within the cavity and having at least two pin-receiving openings, and an actuable locking ring disposed around the cavity.

20 Claims, 5 Drawing Sheets



(51) **Int. Cl.**

H01R 24/20	(2011.01)
H01R 13/24	(2006.01)
H01R 24/86	(2011.01)
A61B 17/29	(2006.01)
H01R 107/00	(2006.01)

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,258,716 A 3/1981 Sutherland
4,278,077 A 7/1981 Mizumoto
4,538,594 A 9/1985 Boebel et al.
4,568,311 A 2/1986 Miyaki
4,736,645 A 4/1988 Zimmer
4,771,652 A 9/1988 Zimmer
4,852,391 A 8/1989 Ruch et al.
4,896,015 A 1/1990 Taboada et al.
4,922,755 A 5/1990 Oshiro et al.
4,922,782 A 5/1990 Kawai
4,990,050 A 2/1991 Tsuge et al.
5,019,968 A 5/1991 Wang et al.
5,172,639 A 12/1992 Wiesman et al.
5,195,388 A 3/1993 Zona et al.
5,201,325 A 4/1993 McEwen et al.
5,271,384 A 12/1993 McEwen et al.
5,284,096 A 2/1994 Pelrine et al.
5,297,443 A 3/1994 Wentz
5,297,536 A 3/1994 Wilk
5,304,899 A 4/1994 Sasaki et al.
5,307,447 A 4/1994 Asano et al.
5,353,807 A 10/1994 DeMarco
5,363,935 A 11/1994 Schempf et al.
5,382,885 A 1/1995 Salcudean et al.
5,441,494 A 1/1995 Oritz
5,388,528 A 2/1995 Pelrine et al.
5,436,542 A 7/1995 Petelin et al.
5,458,131 A 10/1995 Wilk
5,458,583 A 10/1995 McNeely et al.
5,458,598 A 10/1995 Feinberg et al.
5,471,515 A 11/1995 Fossum et al.
5,515,478 A 5/1996 Wang
5,524,180 A 6/1996 Wang et al.
5,553,198 A 9/1996 Wang et al.
5,562,448 A 10/1996 Mushabac
5,588,442 A 12/1996 Scovil et al.
5,620,417 A 4/1997 Jang et al.
5,623,582 A 4/1997 Rosenberg
5,624,380 A 4/1997 Takayama et al.
5,624,398 A 4/1997 Smith et al.
5,632,761 A 5/1997 Smith et al.
5,645,520 A 7/1997 Nakamura et al.
5,657,429 A 8/1997 Wang et al.
5,657,584 A 8/1997 Hamlin
5,672,168 A 9/1997 de la Torre et al.
5,674,030 A 10/1997 Sigel
5,728,599 A 3/1998 Rosteker et al.
5,736,821 A 4/1998 Suyaman et al.
5,754,741 A 5/1998 Wang et al.
5,762,458 A 6/1998 Wang et al.
5,769,640 A 6/1998 Jacobus et al.
5,791,231 A 8/1998 Cohn et al.
5,792,135 A 8/1998 Madhani et al.
5,797,538 A 8/1998 Heaton et al.
5,797,900 A 8/1998 Madhani et al.
5,807,377 A 9/1998 Madhani et al.
5,808,665 A 9/1998 Green
5,815,640 A 9/1998 Wang et al.
5,825,982 A 10/1998 Wright et al.
5,841,950 A 11/1998 Wang et al.
5,845,646 A 12/1998 Lemelson
5,855,583 A 1/1999 Wang et al.
5,876,325 A 3/1999 Mizuno et al.
5,878,193 A 3/1999 Wang et al.
5,878,783 A 3/1999 Smart
5,895,417 A 4/1999 Pomeranz et al.
5,906,591 A 5/1999 Dario et al.
5,907,664 A 5/1999 Wang et al.
5,910,129 A 6/1999 Koblish et al.
5,911,036 A 6/1999 Wright et al.
5,971,976 A 10/1999 Wang et al.
5,993,467 A 11/1999 Yoon
6,001,108 A 12/1999 Wang et al.
6,007,550 A 12/1999 Wang et al.
6,030,365 A 2/2000 Laufer
6,031,371 A 2/2000 Smart
6,058,323 A 5/2000 Lemelson
6,063,095 A 5/2000 Wang et al.
6,066,090 A 5/2000 Yoon
6,102,850 A 8/2000 Wang et al.
6,107,795 A 8/2000 Smart
6,132,368 A 10/2000 Cooper
6,132,441 A 10/2000 Grace
6,139,563 A 10/2000 Cosgrove, III et al.
6,156,006 A 12/2000 Brosens et al.
6,159,146 A 12/2000 El Gazayerli
6,162,171 A 12/2000 Ng et al.
D438,617 S 3/2001 Cooper et al.
6,206,903 B1 3/2001 Ramans
D441,076 S 4/2001 Cooper et al.
6,223,100 B1 4/2001 Green
D441,862 S 5/2001 Cooper et al.
6,238,415 B1 5/2001 Sepetka et al.
6,240,312 B1 5/2001 Alfano et al.
6,241,730 B1 6/2001 Alby
6,244,809 B1 6/2001 Wang et al.
6,246,200 B1 6/2001 Blumenkranz et al.
D444,555 S 7/2001 Cooper et al.
6,286,514 B1 9/2001 Lemelson
6,296,635 B1 10/2001 Smith et al.
6,309,397 B1 10/2001 Julian et al.
6,309,403 B1 10/2001 Minoret et al.
6,312,435 B1 11/2001 Wallace et al.
6,321,106 B1 11/2001 Lemelson
6,327,492 B1 12/2001 Lemelson
6,331,181 B1 12/2001 Tiemey et al.
6,346,072 B1 2/2002 Cooper
6,352,503 B1 3/2002 Raifu et al.
6,364,888 B1 4/2002 Niemeyer et al.
6,371,952 B1 4/2002 Madhani et al.
6,394,998 B1 5/2002 Wallace et al.
6,398,726 B1 6/2002 Ramans et al.
6,400,980 B1 6/2002 Lemelson
6,408,224 B1 6/2002 Lemelson
6,424,885 B1 7/2002 Niemeyer et al.
6,432,112 B2 8/2002 Brock et al.
6,436,107 B1 8/2002 Wang et al.
6,441,577 B2 8/2002 Blumenkranz et al.
6,450,104 B1 9/2002 Grant et al.
6,451,027 B1 9/2002 Cooper et al.
6,454,758 B1 9/2002 Thompson et al.
6,459,926 B1 10/2002 Nowlin et al.
6,463,361 B1 10/2002 Wang et al.
6,468,203 B2 10/2002 Belson
6,468,265 B1 10/2002 Evans et al.
6,470,236 B2 10/2002 Ohtsuki
6,491,691 B1 12/2002 Morley et al.
6,491,701 B2 12/2002 Nemeyer et al.
6,493,608 B1 12/2002 Niemeyer et al.
6,496,099 B2 12/2002 Wang et al.
6,508,413 B2 1/2003 Bauer et al.
6,512,345 B2 1/2003 Borenstein
6,522,906 B1 2/2003 Salisbury, Jr. et al.
6,544,276 B1 4/2003 Azizi
6,548,982 B1 4/2003 Papanikolopoulos et al.
6,554,790 B1 4/2003 Moll
6,565,554 B1 5/2003 Niemeyer
6,574,355 B2 6/2003 Green
6,587,750 B2 7/2003 Gerbi et al.
6,591,239 B1 7/2003 McCall et al.
6,594,552 B1 7/2003 Nowlin et al.
6,610,007 B2 8/2003 Belson et al.
6,620,173 B2 9/2003 Gerbi et al.
6,642,836 B1 11/2003 Wang et al.
6,645,196 B1 11/2003 Nixon et al.
6,646,541 B1 11/2003 Wang et al.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,648,814	B2	11/2003	Kim et al.
6,659,939	B2	12/2003	Moll et al.
6,661,571	B1	12/2003	Shioda et al.
6,671,581	B2	12/2003	Niemeyer et al.
6,676,684	B1	1/2004	Morley et al.
6,684,129	B2	1/2004	Salisbury, Jr. et al.
6,685,648	B2	2/2004	Flaherty et al.
6,685,698	B2	2/2004	Morley et al.
6,687,571	B1	2/2004	Byme et al.
6,692,485	B1	2/2004	Brock et al.
6,699,177	B1	3/2004	Wang et al.
6,699,235	B2	3/2004	Wallace et al.
6,702,734	B2	3/2004	Kim et al.
6,702,805	B1	3/2004	Stuart
6,714,839	B2	3/2004	Salisbury, Jr. et al.
6,714,841	B1	3/2004	Wright et al.
6,719,684	B2	4/2004	Kim et al.
6,720,988	B1	4/2004	Gere et al.
6,726,699	B1	4/2004	Wright et al.
6,728,599	B2	4/2004	Wright et al.
6,730,021	B2	5/2004	Vassiliades, Jr. et al.
6,731,988	B1	5/2004	Green
6,746,443	B1	6/2004	Morley et al.
6,764,441	B2	7/2004	Chiel et al.
6,764,445	B2	7/2004	Ramans et al.
6,766,204	B2	7/2004	Niemeyer et al.
6,770,081	B1	8/2004	Cooper et al.
6,774,597	B1	8/2004	Borenstein
6,776,165	B2	8/2004	Jin
6,780,184	B2	8/2004	Tanrisever
6,783,524	B2	8/2004	Anderson et al.
6,785,593	B2	8/2004	Wang et al.
6,788,018	B1	9/2004	Blumenkranz
6,792,663	B2	9/2004	Krzyzanowski
6,793,653	B2	9/2004	Sanchez et al.
6,799,065	B1	9/2004	Niemeyer
6,799,088	B2	9/2004	Wang et al.
6,801,325	B2	10/2004	Farr et al.
6,804,581	B2	10/2004	Wang et al.
6,810,281	B2	10/2004	Brock et al.
6,817,972	B2	11/2004	Snow
6,817,974	B2	11/2004	Cooper et al.
6,817,975	B1	11/2004	Farr et al.
6,820,653	B1	11/2004	Schempf et al.
6,824,508	B2	11/2004	Kim et al.
6,824,510	B2	11/2004	Kim et al.
6,832,988	B2	12/2004	Sprout
6,832,996	B2	12/2004	Woloszko et al.
6,836,703	B2	12/2004	Wang et al.
6,837,846	B2	1/2005	Jaffe et al.
6,837,883	B2	1/2005	Moll et al.
6,839,612	B2	1/2005	Sanchez et al.
6,840,938	B1	1/2005	Morley et al.
6,852,107	B2	2/2005	Wang et al.
6,858,003	B2	2/2005	Evans et al.
6,860,346	B2	3/2005	Burt et al.
6,860,877	B1	3/2005	Sanchez et al.
6,866,671	B2	3/2005	Tiemey et al.
6,870,343	B2	3/2005	Borenstein et al.
6,871,117	B2	3/2005	Wang et al.
6,871,563	B2	3/2005	Choset et al.
6,879,880	B2	4/2005	Nowlin et al.
6,892,112	B2	5/2005	Wang et al.
6,899,705	B2	5/2005	Niemeyer
6,902,560	B1	6/2005	Morley et al.
6,905,460	B2	6/2005	Wang et al.
6,905,491	B1	6/2005	Wang et al.
6,911,916	B1	6/2005	Wang et al.
6,917,176	B2	7/2005	Schempf et al.
6,933,695	B2	8/2005	Blumenkranz
6,936,001	B1	8/2005	Snow
6,936,003	B2	8/2005	Iddan
6,936,042	B2	8/2005	Wallace et al.
6,943,663	B2	9/2005	Wang et al.
6,949,096	B2	9/2005	Davison et al.
6,951,535	B2	10/2005	Ghodoussi et al.
6,965,812	B2	11/2005	Wang et al.
6,974,411	B2	12/2005	Belson
6,974,449	B2	12/2005	Niemeyer
6,979,423	B2	12/2005	Moll
6,984,203	B2	1/2006	Tartaglia et al.
6,984,205	B2	1/2006	Gazdzinski
6,991,627	B2	1/2006	Madhani et al.
6,993,413	B2	1/2006	Sunaoshi
6,994,703	B2	2/2006	Wang et al.
6,994,708	B2	2/2006	Manzo
6,997,908	B2	2/2006	Carrillo, Jr. et al.
7,025,064	B2	4/2006	Wang et al.
7,027,892	B2	4/2006	Wang et al.
7,033,344	B2	4/2006	Imran
7,039,453	B2	5/2006	Mullick
7,042,184	B2	5/2006	Oleynikov et al.
7,048,745	B2	5/2006	Tierney et al.
7,053,752	B2	5/2006	Wang et al.
7,063,682	B1	6/2006	Whayne et al.
7,066,879	B2	6/2006	Fowler et al.
7,066,926	B2	6/2006	Wallace et al.
7,074,179	B2	7/2006	Wang et al.
7,077,446	B2	7/2006	Kameda et al.
7,083,571	B2	8/2006	Wang et al.
7,083,615	B2	8/2006	Peterson et al.
7,087,049	B2	8/2006	Nowlin et al.
7,090,683	B2	8/2006	Brock et al.
7,097,640	B2	8/2006	Wang et al.
7,105,000	B2	9/2006	McBrayer
7,107,090	B2	9/2006	Salisbury, Jr. et al.
7,109,678	B2	9/2006	Kraus et al.
7,118,582	B1	10/2006	Wang et al.
7,121,781	B2	10/2006	Sanchez et al.
7,125,403	B2	10/2006	Julian et al.
7,126,303	B2	10/2006	Farritor et al.
7,147,650	B2	12/2006	Lee
7,155,315	B2	12/2006	Niemeyer et al.
7,169,141	B2	1/2007	Brock et al.
7,182,025	B2	2/2007	Ghorbel et al.
7,182,089	B2	2/2007	Ries
7,199,545	B2	4/2007	Oleynikov et al.
7,206,626	B2	4/2007	Quaid, III
7,206,627	B2	4/2007	Abovitz et al.
7,210,364	B2	5/2007	Ghorbel et al.
7,214,230	B2	5/2007	Brock et al.
7,217,240	B2	5/2007	Snow
7,239,940	B2	7/2007	Wang et al.
7,250,028	B2	7/2007	Julian et al.
7,259,652	B2	8/2007	Wang et al.
7,273,488	B2	9/2007	Nakamura et al.
7,311,107	B2	12/2007	Harel et al.
7,339,341	B2	3/2008	Oleynikov et al.
7,372,229	B2	5/2008	Farritor et al.
7,447,537	B1	11/2008	Funda et al.
7,492,116	B2	2/2009	Oleynikov et al.
7,566,300	B2	7/2009	Devierre et al.
7,574,250	B2	8/2009	Niemeyer
7,637,905	B2	12/2009	Saadat et al.
7,645,230	B2	1/2010	Mikkaichi et al.
7,655,004	B2	2/2010	Long
7,670,329	B2	3/2010	Flaherty et al.
7,731,727	B2	6/2010	Sauer
7,762,825	B2	7/2010	Burbank et al.
7,772,796	B2	8/2010	Farritor et al.
7,785,251	B2	8/2010	Wilk
7,785,333	B2	8/2010	Miyamoto et al.
7,789,825	B2	9/2010	Nobis et al.
7,794,494	B2	9/2010	Sahatjian et al.
7,865,266	B2	1/2011	Moll et al.
7,960,935	B2	6/2011	Farritor et al.
8,021,358	B2	9/2011	Doyle et al.
8,353,897	B2	1/2013	Doyle et al.
9,089,353	B2	7/2015	Farritor et al.
2001/0018591	A1	8/2001	Brock et al.
2001/0049497	A1	12/2001	Kalloo et al.
2002/0003173	A1	1/2002	Bauer et al.
2002/0013601	A1	1/2002	Nobles et al.
2002/0026186	A1	2/2002	Woloszko et al.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2002/0038077	A1	3/2002	de la Torre et al.
2002/0065507	A1	5/2002	Zando-Azizi
2002/0091374	A1	6/2002	Cooper
2002/0103417	A1	8/2002	Gazdzinski
2002/0111535	A1	8/2002	Kim et al.
2002/0120254	A1	8/2002	Julian et al.
2002/0128552	A1	9/2002	Nowlin et al.
2002/0140392	A1	10/2002	Borenstein et al.
2002/0147487	A1	10/2002	Sundquist et al.
2002/0151906	A1	10/2002	Demarais et al.
2002/0156347	A1	10/2002	Kim et al.
2002/0171385	A1	11/2002	Kim et al.
2002/0173700	A1	11/2002	Kim et al.
2002/0190682	A1	12/2002	Schempf et al.
2003/0020810	A1	1/2003	Takizawa et al.
2003/0045888	A1	3/2003	Brock et al.
2003/0065250	A1	4/2003	Chiel et al.
2003/0089267	A1	5/2003	Ghorbel et al.
2003/0092964	A1	5/2003	Kim et al.
2003/0097129	A1	5/2003	Davison et al.
2003/0100817	A1	5/2003	Wang et al.
2003/0114731	A1	6/2003	Cadeddu et al.
2003/0135203	A1	6/2003	Wang et al.
2003/0139742	A1	7/2003	Wampler et al.
2003/0144656	A1	7/2003	Ocel et al.
2003/0167000	A1	9/2003	Mullick
2003/0172871	A1	9/2003	Scherer
2003/0179308	A1	9/2003	Zamorano et al.
2003/0181788	A1	9/2003	Yokoi et al.
2003/0229268	A1	12/2003	Uchiyama et al.
2003/0230372	A1	12/2003	Schmidt
2004/0024311	A1	2/2004	Quaid
2004/0034282	A1	2/2004	Quaid
2004/0034283	A1	2/2004	Quaid
2004/0034302	A1	2/2004	Abovitz et al.
2004/0050394	A1	3/2004	Jin
2004/0070822	A1	4/2004	Shioda et al.
2004/0099175	A1	5/2004	Perrot et al.
2004/0102772	A1	5/2004	Baxter et al.
2004/0106916	A1	6/2004	Quaid et al.
2004/0111113	A1	6/2004	Nakamura et al.
2004/0117032	A1	6/2004	Roth
2004/0138525	A1	7/2004	Saadat et al.
2004/0138552	A1	7/2004	Harel et al.
2004/0140786	A1	7/2004	Borenstein
2004/0153057	A1	8/2004	Davison
2004/0173116	A1	9/2004	Ghorbel et al.
2004/0176664	A1	9/2004	Iddan
2004/0215331	A1	10/2004	Chew et al.
2004/0225229	A1	11/2004	Viola
2004/0254680	A1	12/2004	Sunaoshi
2004/0267326	A1	12/2004	Ocel et al.
2005/0014994	A1	1/2005	Fowler et al.
2005/0021069	A1	1/2005	Feuer et al.
2005/0029978	A1	2/2005	Oleynikov et al.
2005/0043583	A1	2/2005	Killmann et al.
2005/0049462	A1	3/2005	Kanazawa
2005/0054901	A1	3/2005	Yoshino
2005/0054902	A1	3/2005	Konno
2005/0064378	A1	3/2005	Toly
2005/0065400	A1	3/2005	Banik et al.
2005/0083460	A1	4/2005	Hattori et al.
2005/0095650	A1	5/2005	Julius et al.
2005/0096502	A1	5/2005	Khalili
2005/0143644	A1	6/2005	Gilad et al.
2005/0154376	A1	7/2005	Riviere et al.
2005/0165449	A1	7/2005	Cadeddu et al.
2005/0239311	A1*	10/2005	Yokoigawa H01R 13/622 439/311
2005/0283137	A1	12/2005	Doyle et al.
2005/0288555	A1	12/2005	Binmoeller
2005/0288665	A1	12/2005	Woloszko
2006/0020272	A1	1/2006	Gildenberg
2006/0046226	A1	3/2006	Bergler et al.
2006/0119304	A1	6/2006	Farritor et al.
2006/0149135	A1	7/2006	Paz
2006/0152591	A1	7/2006	Lin
2006/0155263	A1	7/2006	Lipow
2006/0195015	A1	8/2006	Mullick et al.
2006/0196301	A1	9/2006	Oleynikov et al.
2006/0198619	A1	9/2006	Oleynikov et al.
2006/0241570	A1	10/2006	Wilk
2006/0241732	A1	10/2006	Denker
2006/0253109	A1	11/2006	Chu
2006/0258954	A1	11/2006	Timberlake et al.
2007/0032701	A1	2/2007	Fowler et al.
2007/0043397	A1	2/2007	Ocel et al.
2007/0055342	A1	3/2007	Wu et al.
2007/0080658	A1	4/2007	Farritor et al.
2007/0106113	A1	5/2007	Ravo
2007/0123748	A1	5/2007	Meglan
2007/0142725	A1	6/2007	Hardin et al.
2007/0156019	A1	7/2007	Larkin et al.
2007/0156211	A1	7/2007	Ferren et al.
2007/0167955	A1	7/2007	Menardiere et al.
2007/0225633	A1	9/2007	Ferren et al.
2007/0225634	A1	9/2007	Ferren et al.
2007/0241714	A1	10/2007	Oleynikov et al.
2007/0244520	A1	10/2007	Ferren et al.
2007/0250064	A1	10/2007	Darois et al.
2007/0255273	A1	11/2007	Fernandez et al.
2008/0004634	A1	1/2008	Farritor et al.
2008/0015565	A1	1/2008	Davison
2008/0015566	A1	1/2008	Livneh
2008/0033569	A1	2/2008	Ferren et al.
2008/0045803	A1	2/2008	Williams et al.
2008/0058835	A1	3/2008	Farritor et al.
2008/0058989	A1	3/2008	Oleynikov et al.
2008/0103440	A1	5/2008	Ferren et al.
2008/0109014	A1	5/2008	de la Pena
2008/0111513	A1	5/2008	Farritor et al.
2008/0119870	A1	5/2008	Williams et al.
2008/0132890	A1	6/2008	Woloszko et al.
2008/0161804	A1	6/2008	Rioux et al.
2008/0164079	A1	7/2008	Ferren et al.
2008/0183033	A1	7/2008	Bern et al.
2008/0221591	A1	9/2008	Farritor et al.
2008/0269557	A1	10/2008	Marescaux et al.
2008/0269562	A1	10/2008	Marescaux et al.
2009/0020724	A1	1/2009	Paffrath
2009/0024142	A1	1/2009	Morales
2009/0048612	A1	2/2009	Farritor et al.
2009/0054909	A1	2/2009	Farritor et al.
2009/0069821	A1	3/2009	Farritor et al.
2009/0076536	A1	3/2009	Rentschler et al.
2009/0137952	A1	5/2009	Ramamurthy et al.
2009/0143787	A9	6/2009	De La Pena
2009/0163929	A1	6/2009	Yeung et al.
2009/0171373	A1	7/2009	Farritor et al.
2009/0234369	A1	9/2009	Bax et al.
2009/0236400	A1	9/2009	Cole et al.
2009/0240246	A1	9/2009	Devill et al.
2009/0247821	A1	10/2009	Rogers
2009/0248038	A1	10/2009	Blumenkranz et al.
2009/0281377	A1	11/2009	Newell et al.
2009/0305210	A1	12/2009	Guru et al.
2010/0010294	A1	1/2010	Conlon et al.
2010/0016659	A1	1/2010	Weitzner et al.
2010/0016853	A1	1/2010	Burbank
2010/0042097	A1	2/2010	Newton et al.
2010/0056863	A1	3/2010	Takumi et al.
2010/0069710	A1	3/2010	Yamatani et al.
2010/0069940	A1	3/2010	Miller et al.
2010/0081875	A1	4/2010	Fowler et al.
2010/0139436	A1	6/2010	Kawashima et al.
2010/0198231	A1	8/2010	Manzo et al.
2010/0245549	A1	9/2010	Allen et al.
2010/0262162	A1	10/2010	Omori
2010/0286480	A1	11/2010	Peine et al.
2010/0292691	A1	11/2010	Brogna
2010/0318059	A1	12/2010	Farritor et al.
2011/0020779	A1	1/2011	Hannaford et al.
2011/0071347	A1	3/2011	Rogers et al.
2011/0071544	A1	3/2011	Steger et al.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2011/0098529	A1	4/2011	Ostrovsky et al.
2011/0132960	A1	6/2011	Whitman et al.
2011/0224605	A1	9/2011	Farritor et al.
2011/0230894	A1	9/2011	Simaan et al.
2011/0237890	A1	9/2011	Farritor et al.
2011/0238080	A1	9/2011	Ranjit et al.
2011/0264078	A1	10/2011	Lipow et al.
2011/0270443	A1	11/2011	Kamiya et al.
2012/0035582	A1	2/2012	Nelson et al.
2012/0109150	A1	5/2012	Quaid et al.
2012/0116362	A1	5/2012	Kieturakis
2012/0179168	A1	7/2012	Farritor et al.
2012/0253515	A1	10/2012	Coste-Maniere et al.
2013/0131695	A1	5/2013	Scarfogliero et al.
2013/0345717	A1	12/2013	Markvicka et al.
2014/0039515	A1	2/2014	Mondry et al.
2014/0046340	A1	2/2014	Wilson et al.
2014/0058205	A1	2/2014	Frederick et al.
2014/0249474	A1	9/2014	Suon et al.
2014/0303434	A1	10/2014	Farritor et al.
2014/0373652	A1	12/2014	Zergiebel et al.
2015/0051446	A1	2/2015	Farritor et al.
2016/0143688	A1	5/2016	Orban, III et al.

FOREIGN PATENT DOCUMENTS

EP	1354670		10/2003
EP	2286756		2/2011
EP	2286756	A1	2/2011
EP	2329787		6/2011
EP	2563261		3/2013
EP	2684528	A1	1/2014
EP	2815705	A1	12/2014
EP	2881046	A2	10/2015
EP	2937047	A1	10/2015
JP	05-115425		5/1993
JP	2006508049		9/1994
JP	07-016235		1/1995
JP	07-136173		5/1995
JP	7306155		11/1995
JP	08-224248		9/1996
JP	2001500510		1/2001
JP	2001505810		5/2001
JP	2003220065		8/2003
JP	2004144533		5/2004
JP	2004-180781		7/2004
JP	2004322310		11/2004
JP	2004329292		11/2004
JP	2006507809		3/2006
JP	2009106606		5/2009
JP	2010533045		10/2010
JP	2010536436		12/2010
JP	2011504794		2/2011
JP	2011045500		3/2011
JP	2011115591		6/2011
WO	199221291		5/1991
WO	2001089405		11/2001
WO	2002082979		10/2002
WO	2002100256		12/2002
WO	2005009211		7/2004
WO	2005044095		5/2005
WO	2006052927		8/2005
WO	2006005075		1/2006
WO	2006079108		1/2006
WO	2006079108		7/2006
WO	2007011654		1/2007
WO	2007111571		10/2007
WO	2007149559		12/2007
WO	2009023851		2/2009
WO	2009144729		12/2009
WO	2010050771		5/2010
WO	2011075693		6/2011
WO	2011118646		9/2011
WO	2011135503		11/2011
WO	2013009887		1/2013
WO	2014011238		1/2014

OTHER PUBLICATIONS

Franklin et al., "Prospective Comparison of Open vs. Laparoscopic Colon Surgery for Carcinoma: Five-Year Results," Dis Colon Rectum, 1996; 39: S35-S46.

Flynn et al., "Tomorrow's surgery: micromotors and microrobots for minimally invasive procedures," Minimally Invasive Surgery & Allied Technologies, 1998; 7(4): 343-352.

Fireman et al., "Diagnosing small bowel Crohn's desease with wireless capsule endoscopy," Gut 2003; 52: 390-392.

Fearing et al., "Wing Transmission for a Micromechanical Flying Insect," Proceedings of the 2000 IEEE International Conference to Robotics & Automation, Apr. 2000; 1509-1516.

Faraz et al., "Engineering Approaches to Mechanical and Robotic Design for Minimaly Invasive Surgery (MIS)," Kluwer Academic Publishers (Boston), 2000, 13pp.

Falcone et al., "Robotic Surgery," Clin. Obstet. Gynecol. 2003, 46(1): 37-13.

Fraulob et al., "Miniature assistance module for robot-assisted heart surgery," Biomed. Tech. 2002, 47 Suppl. 1, Pt. 1: 12-15.

Fukuda et al., "Mechanism and Swimming Experiment of Micro Mobile Robot in Water," Proceedings of the 1994 EEE International Conference on Robotics and Automation, 1994: 814-819.

Fukuda et al., "Micro Active Catheter System with Multi Degrees of Freedom," Proceedings of the IEEE International Conference on Robotics and Automation, May 1994, pp. 2290-2295.

Fuller et al., "Laparoscopic Trocar Injuries: A Report from a U.S. Food and Drug Administration (FDA) Center for Devices and Radiological Health (CDRH) Systematic Technology Assessment of Medical Products (STAMP) Committe," U.S. Food and Drug Adminstration, available at http://www.fdaJ:?;ov, Finalized: Nov. 7, 2003; Updated: Jun. 24, 2005, 11 pp.

Dumpert et al., "Improving in Vivo Robot Visioin Quality," from the Proceedings of Medicine Meets Virtual Realtiy, Long Beach, CA, Jan. 26-29, 2005. 1 pg.

Dakin et al., "Comparison of laparoscopic skills performance between standard instruments and two surgical robotic systems," Surg Endosc., 2003; 17: 574-579.

Cuschieri, "Technology for Minimal Access Surgery," BMJ, 1999, 319: 1-6.

Grady, "Doctors Try New Surgery for Gallbladder Removal," The New York Times, Apr. 20, 2007, 3 pp.

Choi et al., "Flexure-based Manipulator for Active Handheld Microsurgical Instrument," Proceedings of the 27th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBS), Sep. 2005, 4pp.

Chanthasopeephan et al., (2003), "Measuring Forces in Liver Cutting: New Equipment and Experimenal Results," Annals of Biomedical Engineering 31:1372-1382.

Cavusoglu et al., "Robotics for Telesurgery: Second Generation Berkeley/UCSF Laparoscopic Telesurgical Workstation and Looking Towards the Future Applications," Industrial Robot: An International Journal, 2003; 30(1):22-29.

Guber et al., "Miniaturized Instrument Systems for Minimally Invasive Diagnosis and Therapy," Biomedizinische Technic 2002, Band 47, Erganmngsband 1: 198-201.

Abbott et al., "Design of an Endoluminal NOTES Robotic System," from the Proceedings of the 2007 IEEE/RSJ Int'l Conf. on Intelligent Robot Systems, San Diego, CA, Oct. 29-Nov. 2, 2007, pp. 410-416.

Allendorf et al., "Postoperative Immune Function Varies Inversely with the Degree of Surgical Trauma in a Murine Model," Surgical Endoscopy 1997; 11:427-430.

Ang, "Active Tremor Compensation in Handheld Instrument for Microsurgery," Doctoral Dissertation, tech report CMU-RI-TR-04-28, Robotics Institute, Carnegie Mellon Unviersity, May 2004, 167pp.

Atmel 80C5X2 Core, http://www.atmel.com, 2006, 186pp.

(56) **References Cited**

OTHER PUBLICATIONS

Bailey et al., "Complications of Laparoscopic Surgery," Quality Medical Publishers, Inc., 1995, 25pp.
Ballantyne, "Robotic Surgery, Telerobotic Surgery, Telepresence, and Telementoring," Surgical Endoscopy, 2002; 16: 1389-1402.
Bauer et al., "Case Report: Remote Percutaneous Renal Percutaneous Renal Access Using a New Automated Telesurgical Robotic System," Telemedicine Journal and e-Health 2001; (4): 341-347.
Begos et al., "Laparoscopic Cholecystectomy: From Gimmick to Gold Standard," J Clin Gastroenterol, 1994; 19(4): 325-330.
Berg et al., "Surgery with Cooperative Robots," Medicine Meets Virtual Reality, Feb. 2007, 1 pg.
Breda et al., "Future developments and perspectives in laparoscopy," Eur. Urology 2001; 40(1): 84-91.
Breedveld et al., "Design of Steerable Endoscopes to Improve the Visual Perception of Depth During Laparoscopic Surgery," ASME, Jan. 2004; vol. 126, pp. 1-5.
Breedveld et al., "Locomotion through the Intestine by means of Rolling Stents," Proceedings of the ASME Design Engineering Technical Conferences, 2004, pp. 1-7.
Calafiore et al., Multiple Arterial Conduits Without Cardiopulmonary Bypass: Early Angiographic Results,: Ann Thorac Surg, 1999; 67: 450-456.
Camarillo et al., "Robotic Technology in Surgery: Past, Present and Future," The American Journal of Surgery, 2004; 188: 2S-15.
Cavusoglu et al., "Telesurgery and Surgical Simulation: Haptic Interfaces to Real and Virtual Surgical Environments," In McLaughliin, M.L., Hespanha, J.P., and Sukhatme, G., editors. Touch in virtual environments, IMSC Series in Multimedia 2001, 28pp.
Dumpert et al., "Stereoscopic In Vivo Surgical Robots," IEEE Sensors Special Issue on In Vivo Sensors for Medicine, Jan. 2007, 10 pp.
Green, "Telepresence Surgery", Jan. 1, 1995, Publisher: IEEE Engineering in Medicine and Biology.
Cleary et al., "State of the Art in Surgical Rooties: Clinical Applications and Technology Challenges", "Computer Aided Surgery", Jan. 1, 2002, pp. 312-328, vol. 6.
Stoianovici et al., "Robotic Tools for Minimally Invasive Urologic Surgery", Jan. 1, 2002, pp. 1-17.

* cited by examiner

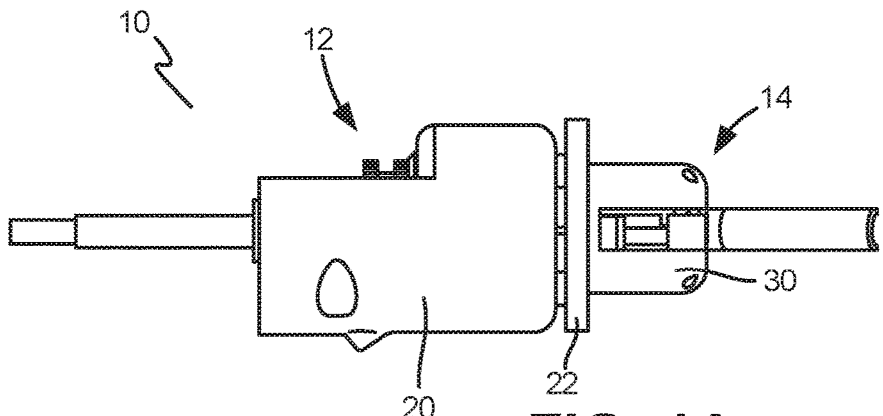


FIG. 1A

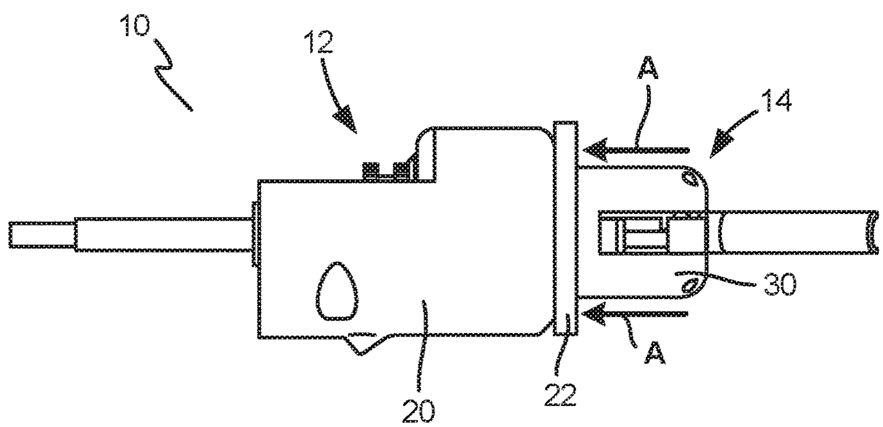


FIG. 1B

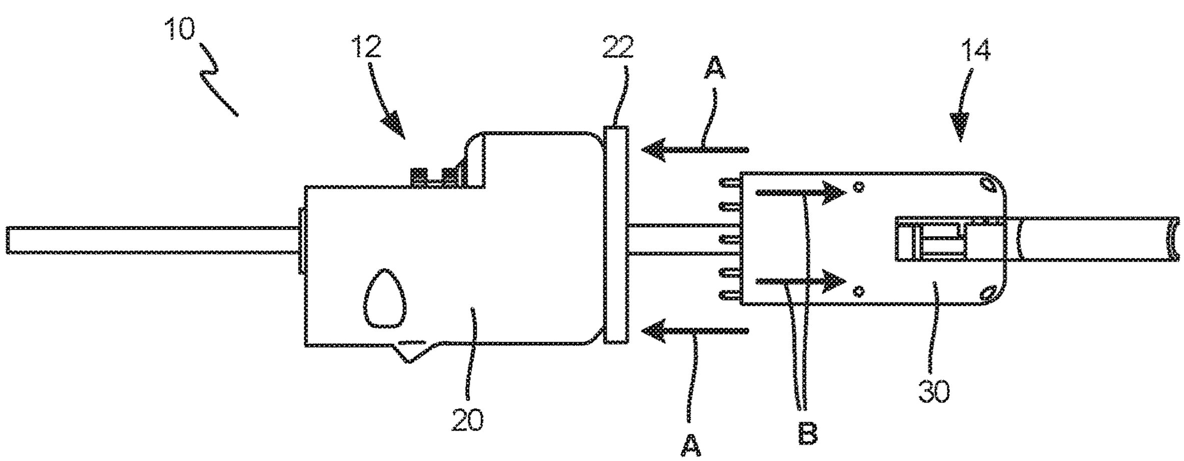


FIG. 1C

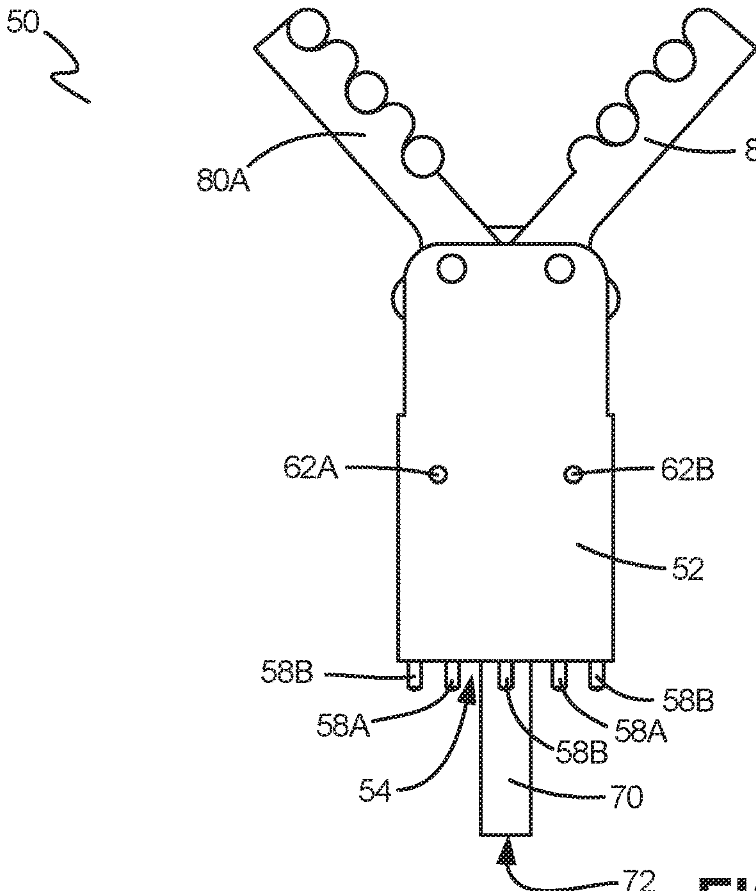

50
80A
80B
62A
62B
52
58B
58A
58B
58A
58B
54
70
72

FIG. 2A

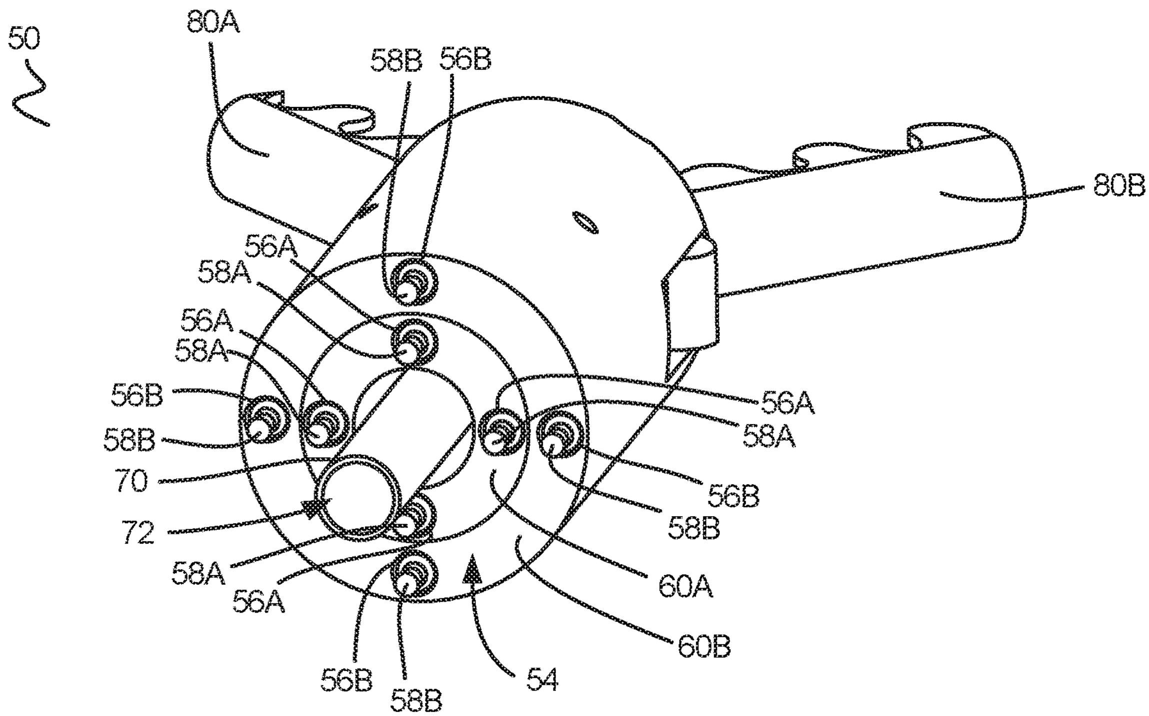

50
80A
58B
56B
80B
56A
58A
56A
58A
56B
58B
70
72
58A
56A
56A
58A
56B
58B
60A
60B
56B
58B
54

FIG. 2B

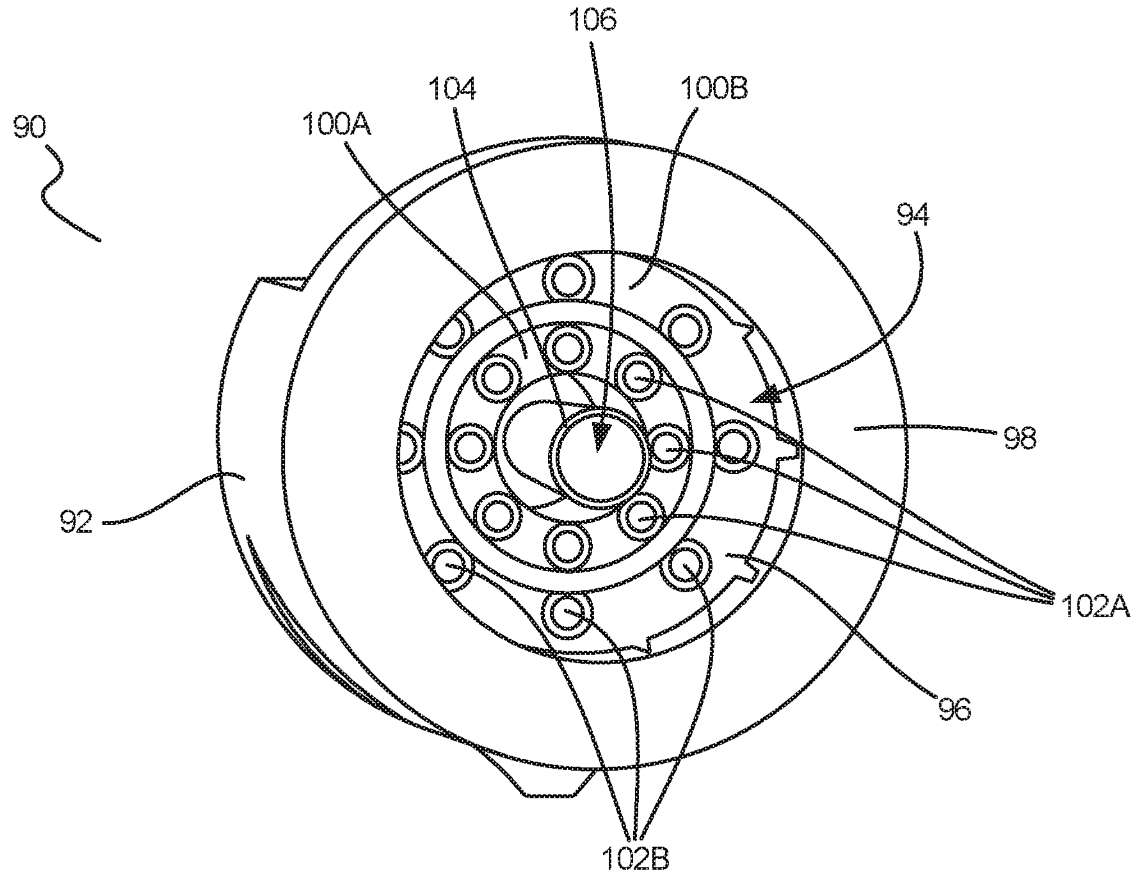

106
104
100B
100A
90
94
98
92
102A
96
102B

FIG. 3

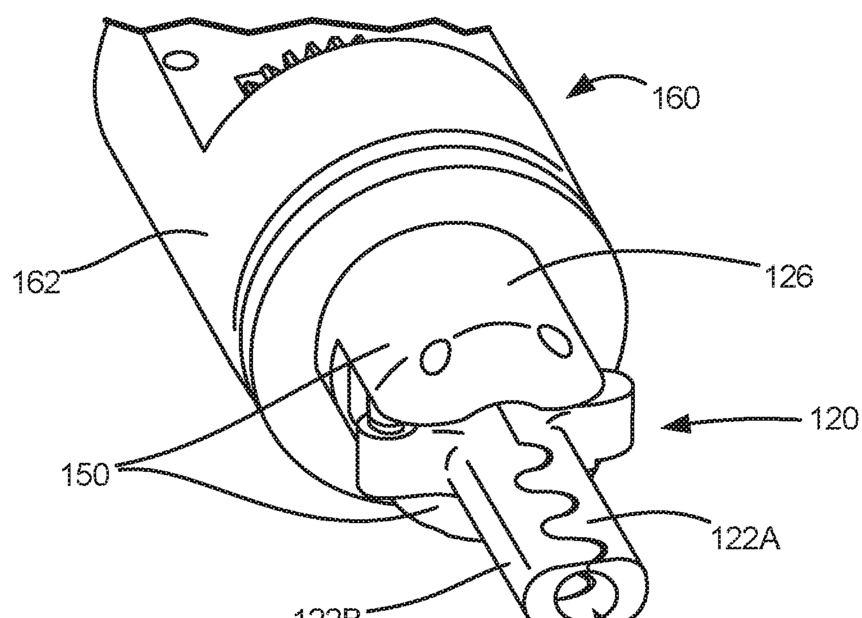

160
162
126
120
150
122A
122B
124

FIG. 4A

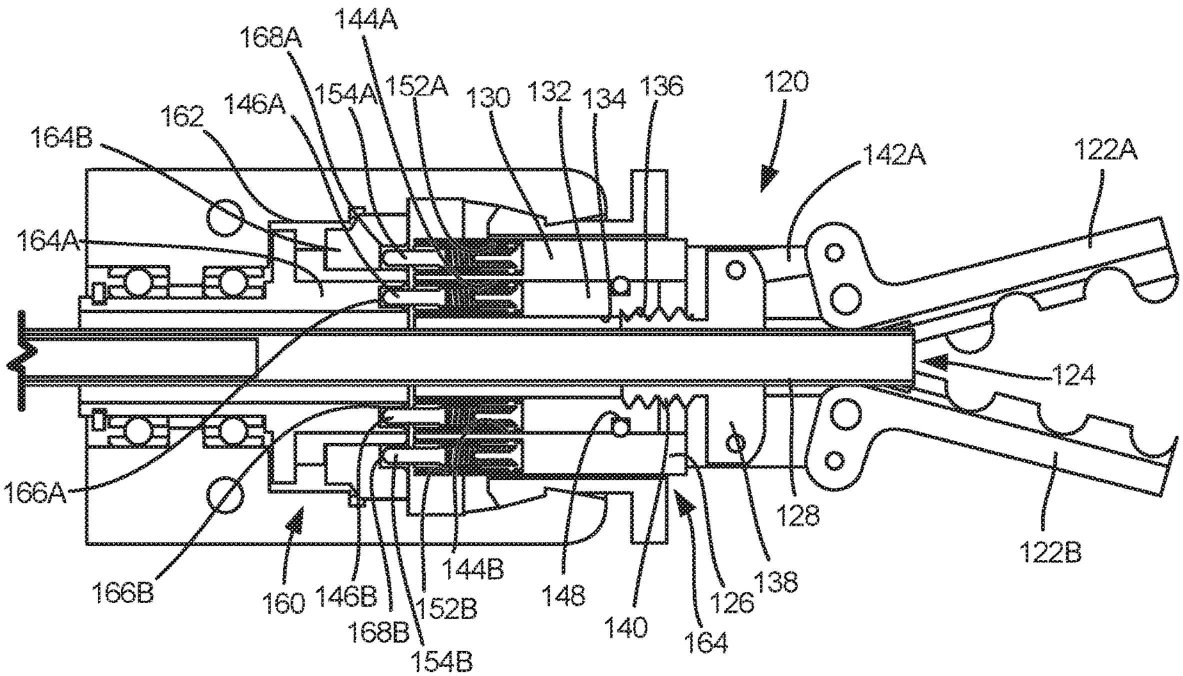

144A
168A
152A
154A
130
132
134
136
120
146A
162
164B
142A
122A
164A
124
166A
128
122B
138
166B
146B
144B
148
126
160
152B
140
164
168B
154B

FIG. 4B

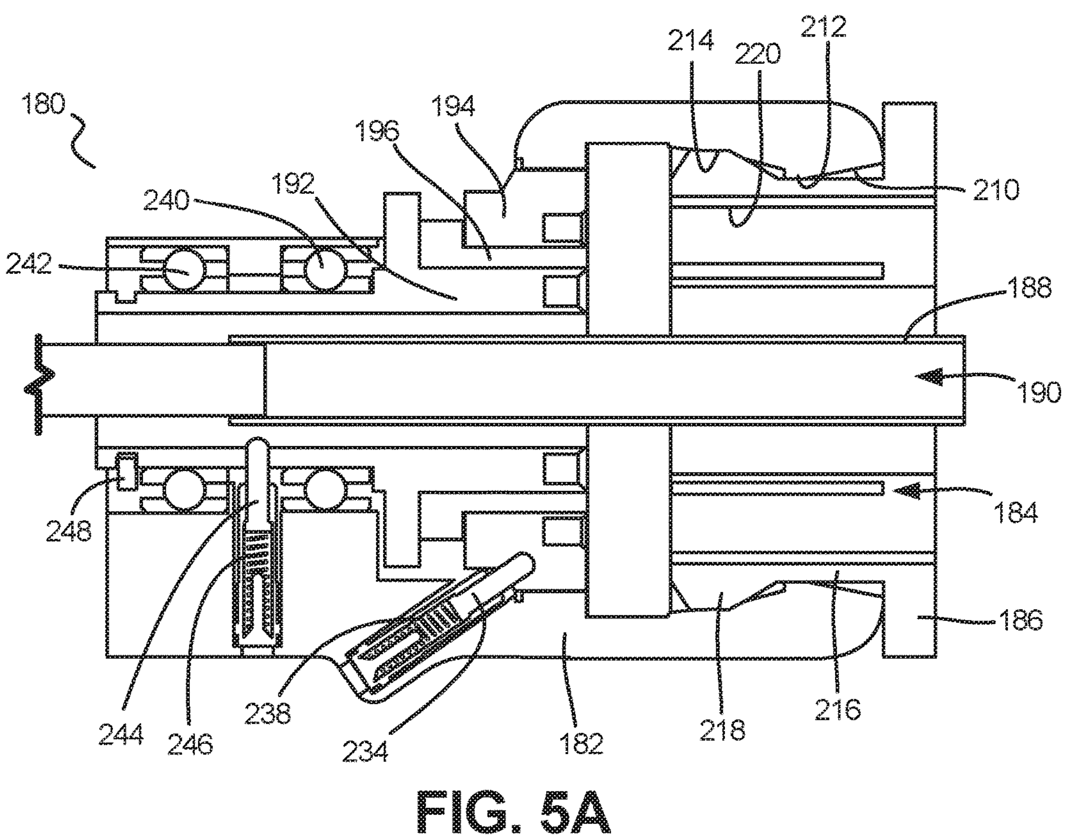

214
212
220
180
194
196
192
210
240
242
188
190
184
248
186
238
216
244
246
234
182
218

FIG. 5A

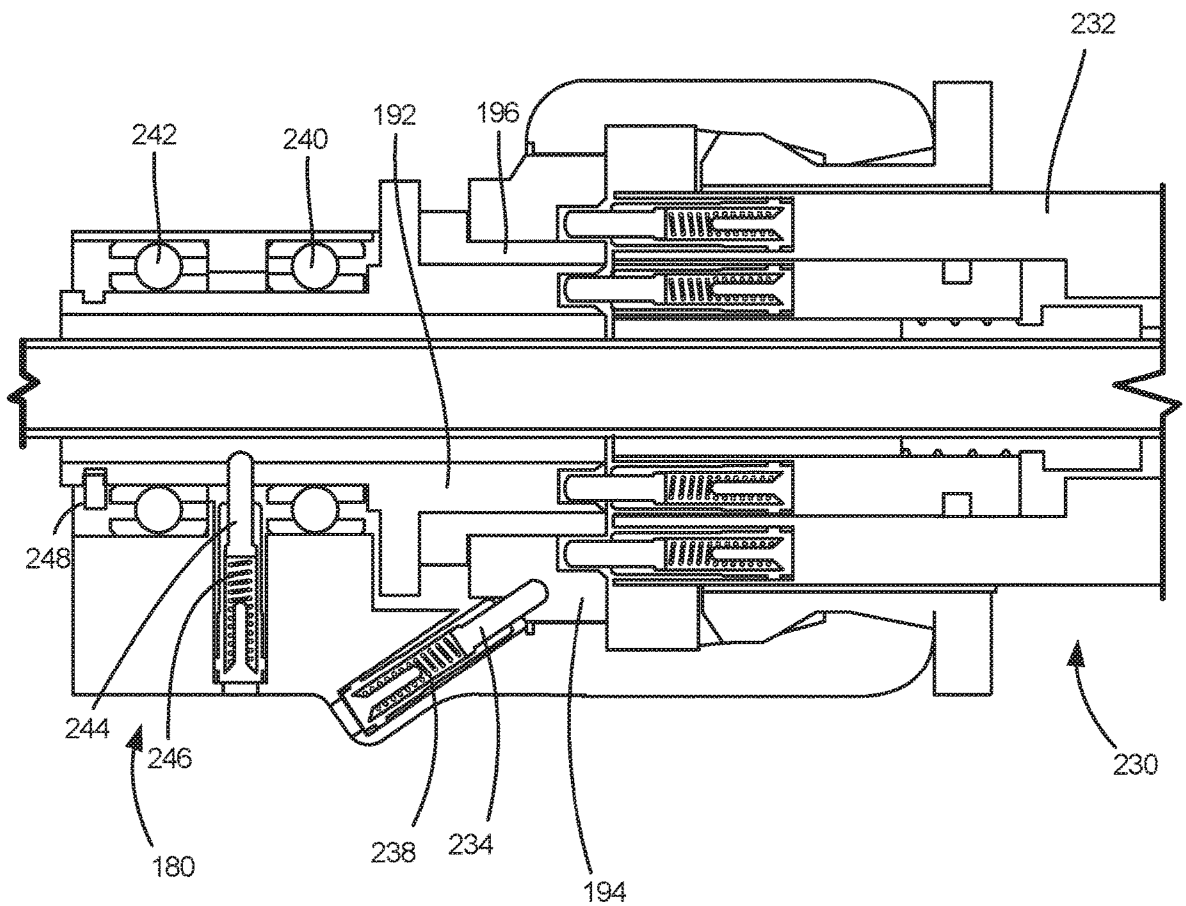


FIG. 5B

QUICK-RELEASE END EFFECTOR TOOL INTERFACE

CROSS-REFERENCE TO RELATED APPLICATION(S)

This application claims the benefit under 35 U.S.C. § 119(e) to U.S. Provisional Application 62/379,344, filed Aug. 24, 2016 and entitled "Quick-Release End Effector Tool Coupler," which is hereby incorporated herein by reference in its entirety.

GOVERNMENT SUPPORT

This invention was made with government support under Grant No. W81XWH-14-1-0058, awarded by the U.S. Army Medical Research Acquisition ACT. The government has certain rights in the invention.

FIELD OF THE INVENTION

The various embodiments herein relate to coupling mechanisms that provide for quick coupling to and quick release from a medical device tool such as, for example, an end effector. The various coupling mechanism embodiments can be incorporated into or attached to various types of medical devices, including robotic surgical devices and systems.

BACKGROUND OF THE INVENTION

Many known surgical device systems, including robotic systems, utilize a tool coupler that consists of concentric splines and a quarter-turn system to lock the tool into the front of the device (or an arm thereof). In other words, the coupler requires that the tool be positioned in the coupler on the device and rotated ¼ turn to align the concentric splines and thereby couple or attach the tool to the device. In these known couplers, once the tool is attached to the device, the concentric splines also operate to transfer rotary motion from the device to the tool.

There is a need in the art for an improved end effector tool coupler for use with various types of medical devices.

BRIEF SUMMARY OF THE INVENTION

Discussed herein are various coupling mechanisms, apparatuses, and components for quick-release attachment of various medical tools to various medical devices and systems.

In Example 1, a coupling apparatus for a medical device comprises a coupler body, a cavity defined in a distal end of the coupler body, a rotatable drive component disposed within the cavity, the drive component comprising at least two pin-receiving openings, and an actuable locking ring disposed around the cavity.

Example 2 relates to the coupling apparatus according to Example 1, wherein the coupler body is coupleable to a tool, wherein the tool comprises a tool body sized and arranged to be positionable within the cavity and a rotatable driven component operably coupled to the tool body. The rotatable driven component comprises at least two pin chambers defined in the rotatable driven component, and at least two tensioned pins, wherein each of the at least two tensioned pins is disposed within and is extendable from one of the at least two pin chambers comprising at least two tensioned pins extending therefrom. The rotatable driven component is alignable with the rotatable drive component such that the at least two tensioned pins extend into the at least two pin-receiving openings.

Example 3 relates to the coupling apparatus according to Example 1, wherein the rotatable drive component comprises an inner drive component comprising at least two inner pin-receiving openings, and an outer drive component comprising at least two outer pin-receiving openings.

Example 4 relates to the coupling apparatus according to Example 3, wherein the coupler body is coupleable to a tool, wherein the tool comprises a tool body sized and arranged to be positionable within the cavity, and a rotatable driven component operably coupled to the tool body. The rotatable driven component comprises an inner driven component comprising at least two inner pin chambers defined in the inner driven component and at least two inner tensioned pins disposed within and extendable from the at least two inner pin chambers, and an outer driven component comprising at least two outer pin chambers defined in the outer driven component and at least two outer tensioned pins disposed within and extendable from the at least two outer pin chambers. The inner driven component is alignable with the inner drive component such that the at least two inner tensioned pins extend into the at least two inner pin-receiving openings, and the outer driven component is alignable with the outer drive component such that the at least two outer tensioned pins extend into the at least two outer pin-receiving openings.

Example 5 relates to the coupling apparatus according to Example 3, further comprising an insulation layer disposed between the inner and outer drive components.

Example 6 relates to the coupling apparatus according to Example 1, wherein the actuable locking ring is movable between a depressed position in which any tool body disposed within the cavity is releasable and a non-depressed position in which any tool body disposed within the cavity is locked therein.

Example 7 relates to the coupling apparatus according to Example 1, further comprising an elongate tube disposed through a length of the coupler body such that the rotatable drive component is disposed around a distal portion of the elongate tube, the elongate tube comprising a lumen in fluid communication with a distal opening of the elongate tube.

In Example 8, a coupling system for a medical device comprises a coupling apparatus associated with the medical device and a tool body coupleable with the coupling apparatus. The apparatus comprises a coupler body, a cavity defined in a distal end of the coupler body, a rotatable drive component disposed within the cavity, the drive component comprising at least two pin-receiving openings, and an actuable locking ring disposed around the cavity. The tool body is sized and arranged to be positionable within the cavity and comprises a rotatable driven component operably coupled to the tool body. The rotatable driven component comprises at least two pin chambers defined in the rotatable driven component, and at least two tensioned pins disposed within and extendable from the at least two pin chambers. The rotatable driven component is alignable with the rotatable drive component such that the at least two tensioned pins extend into the at least two pin-receiving openings.

Example 9 relates to the coupling system according to Example 8, wherein the rotatable drive component comprises an inner drive component comprising at least two inner pin-receiving openings, and an outer drive component comprising at least two outer pin-receiving openings.

Example 10 relates to the coupling system according to Example 9, wherein the rotatable driven component comprises a rotatable inner driven component, wherein the at least two pin chambers comprise at least two inner pin chambers defined in the rotatable inner driven component, and wherein the at least two tensioned pins comprise at least two inner tensioned pins disposed within and extendable from the at least two inner pin chambers, and a rotatable outer driven component, wherein the at least two pin chambers comprise at least two outer pin chambers defined in the rotatable outer driven component, and wherein the at least two tensioned pins comprise at least two outer tensioned pins disposed within and extendable from the at least two outer pin chambers. The rotatable inner driven component is alignable with the inner drive component such that the at least two inner tensioned pins extend into the at least two inner pin-receiving openings, and the rotatable outer driven component is alignable with the outer drive component such that the at least two outer tensioned pins extend into the at least two outer pin-receiving openings.

Example 11 relates to the coupling system according to Example 9, further comprising an insulation layer disposed between the inner and outer drive components.

Example 12 relates to the coupling system according to Example 8, wherein the actuable locking ring is movable between a depressed position in which the tool body is releasable from the cavity and a non-depressed position in which the tool body disposed within the cavity is locked therein.

Example 13 relates to the coupling system according to Example 8, further comprising an elongate tube disposed through a length of the coupler body such that the rotatable drive component is disposed around a distal portion of the elongate tube, the elongate tube comprising a lumen in fluid communication with a distal opening of the elongate tube.

In Example 14, a coupling system for a medical device comprises a coupling apparatus associated with the medical device and a tool body coupleable with the coupling apparatus. The coupling apparatus comprises a coupler body, a cavity defined in a distal end of the coupler body, an inner drive component comprising at least two inner pin-receiving openings, an outer drive component comprising at least two outer pin-receiving openings, and an actuable locking ring disposed around the cavity. The tool body is sized and arranged to be positionable within the cavity and comprises a rotatable inner driven component and a rotatable outer driven component. The rotatable inner driven component comprises at least two inner pin chambers defined in the rotatable inner driven component, and at least two inner tensioned pins disposed within and extendable from the at least two inner pin chambers. The rotatable outer driven component comprises at least two outer pin chambers defined in the rotatable outer driven component, and at least two outer tensioned pins disposed within and extendable from the at least two outer pin chambers. The rotatable inner driven component is alignable with the inner drive component such that the at least two inner tensioned pins extend into the at least two inner pin-receiving openings, and the rotatable outer driven component is alignable with the outer drive component such that the at least two outer tensioned pins extend into the at least two outer pin-receiving openings.

Example 15 relates to the coupling system according to Example 14, further comprising an insulation layer disposed between the inner and outer drive components.

Example 16 relates to the coupling system according to Example 14, wherein the actuable locking ring is movable between a depressed position in which the tool body is releasable from the cavity and a non-depressed position in which the tool body disposed within the cavity is locked therein.

Example 17 relates to the coupling system according to Example 14, further comprising an elongate tube disposed through a length of the coupler body such that the rotatable drive component is disposed around a distal portion of the elongate tube, the elongate tube comprising a lumen in fluid communication with a distal opening of the elongate tube.

In Example 18, a method of coupling a tool to a medical device comprises positioning a rotatable driven component of a tool into a cavity of a coupling apparatus, the coupling apparatus comprising a rotatable drive component disposed within the cavity, wherein the rotatable drive component comprises at least two pin-receiving openings, and wherein the rotatable driven component comprises at least two pin chambers and at least two tensioned pins disposed within and extendable from the at least two pin chambers, and urging the rotatable driven component toward the rotatable drive component, whereby the at least two tensioned pins are urged into the at least two pin-receiving openings such that the rotatable drive component and the rotatable driven component are rotatably coupled.

In Example 19, a method of coupling a tool to a medical device comprises positioning a rotatable driven component of a tool into a cavity of a coupling apparatus, the coupling apparatus comprising a rotatable drive component disposed within the cavity, wherein the rotatable drive component comprises at least two pin-receiving openings, and wherein the rotatable driven component comprises at least two pin chambers and at least two tensioned pins disposed within and extendable from the at least two pin chambers, urging the rotatable driven component toward the rotatable drive component, whereby the at least two tensioned pins are urged into contact with the rotatable drive component such that the at least two tensioned pins are urged into the at least two pin chambers, and rotating the rotatable drive component in relation to the rotatable driven component until the at least two pin-receiving openings align with the at least two pin chambers such that the at least two tensioned pins are urged into the at least two pin-receiving openings such that the rotatable drive component and the rotatable driven component are rotatably coupled.

While multiple embodiments are disclosed, still other embodiments of the present invention will become apparent to those skilled in the art from the following detailed description, which shows and describes illustrative embodiments of the invention. As will be realized, the invention is capable of modifications in various obvious aspects, all without departing from the spirit and scope of the present invention. Accordingly, the drawings and detailed description are to be regarded as illustrative in nature and not restrictive.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A is a side view of a coupling mechanism coupled to a device tool, according to one embodiment.

FIG. **1**B is a side view of the coupling mechanism and device tool of FIG. **1**A in which the locking mechanism has been depressed, according to one embodiment.

FIG. **1**C is a side view of the coupling mechanism and device tool of FIG. **1**A in which the device tool is being uncoupled from the coupling mechanism, according to one embodiment.

FIG. **2**A is a side view of a graspers end effector, according to one embodiment.

FIG. 2B is a perspective rear view of the graspers end effector of FIG. 2A.

FIG. 3 is a perspective front view of a coupling mechanism, according to another embodiment.

FIG. 4A is a perspective front view of a graspers end effector, according to another embodiment.

FIG. 4B is a side cutaway view of the graspers end effector of FIG. 4A coupled to a coupling mechanism, according to one embodiment.

FIG. 5A is a side cutaway view of a coupling mechanism, according to one embodiment.

FIG. 5B is a side cutaway view of the coupling mechanism of FIG. 5A coupled to a device tool, according to one embodiment.

DETAILED DESCRIPTION

The various systems and devices disclosed herein relate to devices for use in medical procedures and systems. More specifically, various embodiments relate to a quick-change coupling apparatus or component that can be used to releasably couple a tool or end effector to a medical device or a component thereof (such as, for example, an arm of the device). For example, in certain implementations, the medical device is a robotic surgical device with an arm having the coupling mechanism disposed on the arm such that one or more end effectors can be coupled to and detached from the arm via the coupling mechanism.

Rather than the known quarter-turn configuration as discussed above, the implementations disclosed or contemplated herein relate to a self-locking quick release mechanism that includes a spring-loaded coupling component (also referred to herein as an "coupler" or "coupler) (rather than concentric splines) that provides for a compliant passage of actuation forces without requiring any type of alignment step during the process of coupling the tool to the coupling component.

The various systems and devices disclosed herein relate to devices, or components thereof, for use in medical procedures and systems. More specifically, various embodiments relate to various medical devices, including robotic devices and related methods and systems.

It is understood that the various embodiments of robotic devices and related methods and systems disclosed herein can be incorporated into or used with any other known medical devices, systems, and methods. For example, the various embodiments disclosed herein may be incorporated into or used with any of the medical devices and systems disclosed in U.S. Pat. No. 8,968,332 (issued on Mar. 3, 2015 and entitled "Magnetically Coupleable Robotic Devices and Related Methods"), U.S. Pat. No. 8,834,488 (issued on Sep. 16, 2014 and entitled "Magnetically Coupleable Surgical Robotic Devices and Related Methods"), U.S. patent application Ser. No. 14/617,232 (filed on Feb. 9, 2015 and entitled "Robotic Surgical Devices and Related Methods"), U.S. Pat. No. 9,579,088 (issued on Feb. 28, 2017 and entitled "Methods, Systems, and Devices for Surgical Visualization and Device Manipulation"), U.S. Pat. No. 8,343,171 (issued on Jan. 1, 2013 and entitled "Methods and Systems of Actuation in Robotic Devices"), U.S. Pat. No. 8,828,024 (issued on Sep. 9, 2014 and entitled "Methods and Systems of Actuation in Robotic Devices"), U.S. patent application Ser. No. 14/454,035 (filed Aug. 7, 2014 and entitled "Methods and Systems of Actuation in Robotic Devices"), U.S. patent application Ser. No. 12/192,663 (filed Aug. 15, 2008 and entitled Medical Inflation, Attachment, and Delivery Devices and Related Methods"), U.S. patent application Ser. No. 15/018,530 (filed Feb. 8, 2016 and entitled "Medical Inflation, Attachment, and Delivery Devices and Related Methods"), U.S. Pat. No. 8,974,440 (issued on Mar. 10, 2015 and entitled "Modular and Cooperative Medical Devices and Related Systems and Methods"), U.S. Pat. No. 8,679,096 (issued on Mar. 25, 2014 and entitled "Multifunctional Operational Component for Robotic Devices"), U.S. Pat. No. 9,179,981 (issued on Nov. 10, 2015 and entitled "Multifunctional Operational Component for Robotic Devices"), U.S. patent application Ser. No. 14/936,234 (filed on Nov. 9, 2015 and entitled "Multifunctional Operational Component for Robotic Devices"), U.S. Pat. No. 8,894,633 (issued on Nov. 25, 2014 and entitled "Modular and Cooperative Medical Devices and Related Systems and Methods"), U.S. Pat. No. 8,968,267 (issued on Mar. 3, 2015 and entitled "Methods and Systems for Handling or Delivering Materials for Natural Orifice Surgery"), U.S. Pat. No. 9,060,781 (issued on Jun. 23, 2015 and entitled "Methods, Systems, and Devices Relating to Surgical End Effectors"), U.S. patent application Ser. No. 14/745,487 (filed on Jun. 22, 2015 and entitled "Methods, Systems, and Devices Relating to Surgical End Effectors"), U.S. Pat. No. 9,089,353 (issued on Jul. 28, 2015 and entitled "Robotic Surgical Devices, Systems, and Related Methods"), U.S. patent application Ser. No. 14/800,423 (filed on Jul. 15, 2015 and entitled "Robotic Surgical Devices, Systems, and Related Methods"), U.S. patent application Ser. No. 13/573,849 (filed Oct. 9, 2012 and entitled "Robotic Surgical Devices, Systems, and Related Methods"), U.S. patent application Ser. No. 13/738,706 (filed Jan. 10, 2013 and entitled "Methods, Systems, and Devices for Surgical Access and Insertion"), U.S. patent application Ser. No. 13/833,605 (filed Mar. 15, 2013 and entitled "Robotic Surgical Devices, Systems, and Related Methods"), U.S. patent application Ser. No. 14/661,465 (filed Mar. 18, 2015 and entitled "Methods, Systems, and Devices for Surgical Access and Insertion"), U.S. Pat. No. 9,498,292 (issued on Nov. 22, 2016 and entitled "Single Site Robotic Devices and Related Systems and Methods"), U.S. patent application Ser. No. 15/357,663 (filed Nov. 21, 2016 and entitled "Single Site Robotic Devices and Related Systems and Methods"), U.S. Pat. No. 9,010,214 (issued on Apr. 21, 2015 and entitled "Local Control Robotic Surgical Devices and Related Methods"), U.S. patent application Ser. No. 14/656,109 (filed on Mar. 12, 2015 and entitled "Local Control Robotic Surgical Devices and Related Methods"), U.S. patent application Ser. No. 14/208,515 (filed Mar. 13, 2014 and entitled "Methods, Systems, and Devices Relating to Robotic Surgical Devices, End Effectors, and Controllers"), U.S. patent application Ser. No. 14/210,934 (filed Mar. 14, 2014 and entitled "Methods, Systems, and Devices Relating to Force Control Surgical Systems), U.S. patent application Ser. No. 14/212,686 (filed Mar. 14, 2014 and entitled "Robotic Surgical Devices, Systems, and Related Methods"), U.S. patent application Ser. No. 14/334,383 (filed Jul. 17, 2014 and entitled "Robotic Surgical Devices, Systems, and Related Methods"), U.S. patent application Ser. No. 14/853,477 (filed Sep. 14, 2015 and entitled "Quick-Release End Effectors and Related Systems and Methods"), U.S. patent application Ser. No. 14/938,667 (filed Nov. 11, 2015 and entitled "Robotic Device with Compact Joint Design and Related Systems and Methods"), U.S. patent application Ser. No. 15/227,813 (filed Aug. 3, 2016 and entitled "Robotic Surgical Devices, Systems, and Related Methods"), U.S. patent application Ser. No. 15/599,231 (filed May 18, 2017 and entitled "Robotic Surgical Devices, Systems, and Related Methods"), U.S. Patent Application 62/381,299 (filed Aug.

30, 2016 and entitled "Robotic Device with Compact Joint Design and an Additional Degree of Freedom and Related Systems and Methods"), U.S. Patent Application 62/425,149 (filed Nov. 22, 2016 and entitled "Improved Gross Positioning Device and Related Systems and Methods"), U.S. Patent Application 62/427,357 (filed Nov. 29, 2016 and entitled "Controller with User Presence Detection and Related Systems and Methods"), U.S. Patent Application 62/433,837 (filed Dec. 14, 2016 and entitled "Releasable Attachment Device for Coupling to Medical Devices and Related Systems and Methods"), and U.S. Pat. No. 7,492,116 (filed on Oct. 31, 2007 and entitled "Robot for Surgical Applications"), U.S. Pat. No. 7,772,796 (filed on Apr. 3, 2007 and entitled "Robot for Surgical Applications"), and U.S. Pat. No. 8,179,073 (issued May 15, 2011, and entitled "Robotic Devices with Agent Delivery Components and Related Methods"), all of which are hereby incorporated herein by reference in their entireties.

Certain device and system implementations disclosed in the applications listed above can be positioned within a body cavity of a patient in combination with a support component similar to those disclosed herein. An "in vivo device" as used herein means any device that can be positioned, operated, or controlled at least in part by a user while being positioned within a body cavity of a patient, including any device that is coupled to a support component such as a rod or other such component that is disposed through an opening or orifice of the body cavity, also including any device positioned substantially against or adjacent to a wall of a body cavity of a patient, further including any such device that is internally actuated (having no external source of motive force), and additionally including any device that may be used laparoscopically or endoscopically during a surgical procedure. As used herein, the terms "robot," and "robotic device" shall refer to any device that can perform a task either automatically or in response to a command.

Certain embodiments provide for insertion of the present invention into the cavity while maintaining sufficient insufflation of the cavity. Further embodiments minimize the physical contact of the surgeon or surgical users with the present invention during the insertion process. Other implementations enhance the safety of the insertion process for the patient and the present invention. For example, some embodiments provide visualization of the present invention as it is being inserted into the patient's cavity to ensure that no damaging contact occurs between the system/device and the patient. In addition, certain embodiments allow for minimization of the incision size/length. Further implementations reduce the complexity of the access/insertion procedure and/or the steps required for the procedure. Other embodiments relate to devices that have minimal profiles, minimal size, or are generally minimal in function and appearance to enhance ease of handling and use.

Certain implementations disclosed herein relate to "combination" or "modular" medical devices that can be assembled in a variety of configurations. For purposes of this application, both "combination device" and "modular device" shall mean any medical device having modular or interchangeable components that can be arranged in a variety of different configurations. The modular components and combination devices disclosed herein also include segmented triangular or quadrangular-shaped combination devices. These devices, which are made up of modular components (also referred to herein as "segments") that are connected to create the triangular or quadrangular configuration, can provide leverage and/or stability during use while also providing for substantial payload space within the device that can be used for larger components or more operational components. As with the various combination devices disclosed and discussed above, according to one embodiment these triangular or quadrangular devices can be positioned inside the body cavity of a patient in the same fashion as those devices discussed and disclosed above.

FIGS. **1A-1C** depict one embodiment of a self-locking quick release mechanism **10** for coupling a device tool **14** to a coupler **12**. It is understood that the coupler **12** is coupled to or integral with a medical device or some component thereof, such that the coupling of a device tool **14** to the coupler **12** results in the device tool **14** being coupled to the medical device. For example, in certain implementations, the coupler **12** is coupled to or integral with a distal end of a robotic arm of the medical device. In more specific implementations, the coupler **12** is coupled to or integral with a distal end of a forearm of a robotic arm of the medical device. The coupler **12** has a coupler body **20** and an actuable locking ring **22**. The actuable locking ring **22** can be depressed (or urged proximally toward the coupler body **20**) as shown by the arrows A in FIG. **1**B to trigger the release of the device tool **14** from the coupler **12**.

The removable device tool **14**, according to some implementations, is an end effector **14** for coupling to an arm of a medical device via the coupler **12**. Alternatively, the end effector **14** is being coupled to a distal end of a forearm of a medical device via the coupler **12**. The removable device tool **14** can have any number of different configurations or can be any one of several different types of tools. Regardless of the configuration of the tool **14**, it has a tool body **30** that is configured to be positionable in and coupleable with the coupler body **20**.

In use, the tool **14** can be removed or uncoupled from the coupler **12** by urging the actuable locking ring **22** proximally toward the coupler body **20** as shown in FIG. **1**B, thereby releasing the tool **14** such that it can be urged distally as shown via the arrows B in FIG. **1**C and removed from the coupler **12**. It is understood that after the tool **14** has been removed, the tool **14** can be re-attached to the coupler **12**—or another tool **14** can be attached thereto—by simply urging the tool **14** proximally into the locking ring **22** such that the tool **14** couples to the coupler **12**.

One exemplary tool **50** that is coupleable to a coupler (such as coupler **12** discussed above) is depicted in FIGS. **2**A and **2**B and has an end effector body **52**. As best shown in FIG. **2**B, the proximal end of the end effector body **52** has pins (also referred to herein as "tensioned pins" or "spring-loaded pins") **58**A, **58**B disposed within and extending from the proximal end **54** of the body **52** in their resting state. Each of the pins **58**A, **58**B is disposed within an opening (also referred to herein as a "pin chamber") **56**A, **56**B defined in the proximal end **54** such that each pin **58**A, **58**B can be urged toward the body **52** into its chamber **56**A, **56**B. That is, each pin **58**A, **58**B is coupled to a force mechanism (not shown) that has a resting state in which the pin **58**A, **58**B is extended from the pin chamber **56**A, **56**B and applies a force to the pin **58**A, **58**B when the pin **58**A, **58**B is urged toward the end effector body **52**. In one embodiment, the force mechanism is a compression spring (not shown). Alternatively, any known force mechanism that operates as described can be used.

In the exemplary embodiment as shown, the end effector body **52** has eight spring-loaded pins **58**A, **58**B, with four pins **58**A disposed in four pin chambers **56**A defined in an inner driven component **60**A and four pins **58**B disposed in four pin chambers **56**B defined in an outer driven component **60**B, wherein the two driven components **60**A, **60**B are concentric or coaxial. That is, the two driven components **60**A, **60**B are separate components that rotate around the same axis. Alternatively, the body **52** can have a number of pins ranging from one pin to any number of pins that can be disposed in chambers on the proximal end **54** of the body **52**. In one specific alternative embodiment, the proximal end **54** has at least four pins disposed in four pin chambers. In a further alternative, the proximal end **54** has at least two pins disposed in two pin chambers.

In this specific implementation, the end effector body **52** also has a central tube **70** disposed therethrough that defines a central lumen **72** within the tube **70**. The central tube **70** can be used in several different capacities, thereby making it possible for the tool **50** to be one of several different types of tools. That is, the tube **70** with its central lumen **72** can be used for suction, irrigation, tool delivery, drug delivery, clip application, and/or biopsy collection, and various other known features of various medical device tools or end effectors.

Alternatively, there are tool configurations that don't require a tube **70** with a lumen **72**, and thus the body **52** according to certain implementations can have no tube. Without the tube **70**, the body **52** can have a smaller diameter. In one specific embodiment in which the body **52** has no tube, the body can have a diameter of around ⅜ inch, thereby allowing the end effector **50** to fit through a standard laparoscopic port (which has an inner diameter of around 10 mm.

In one implementation, the coaxial driven components **60**A, **60**B can rotate in relation to each other, thereby adding an additional degree of freedom to the tool **50**. In alternative embodiments, the body **52** doesn't have two concentric driven components, but instead the body **52** is a single, unitary component.

In the exemplary embodiment as shown in FIGS. **2**A and **2**B, the tool **50** is a set of graspers **50**. That is, the graspers end effector **50** has two grasper arms **80**A, **80**B coupled to the end effector body **52**.

The spring-loaded pins **58**A, **58**B on the tool **50** as described above are configured to operate in conjunction with a corresponding device coupler (such as the coupler **12** discussed above, for example, or any other coupler embodiment disclosed or contemplated herein) to allow for the coupling of the tool body **50** to the coupler without the need for an alignment step. This non-alignment coupling is best described in relation to the coupler to which the body **50** is coupled. One example of a device coupler **90** is depicted in FIG. **3** according to one implementation, in which the coupler **90** has a coupler body **92**, a coupler cavity **94**, a coupler drive component **96** disposed within the cavity **94**, and an actuable locking ring **98** disposed around the cavity **94**. In this specific implementation, the coupler drive component **96** is actually made up of two drive components: a first or inner drive component **100**A and a second or outer drive component **100**B, wherein the drive components **100**A, **100**B are coaxial and rotatable in relation to each other. Further, each of the drive components **100**A, **100**B has pin-receiving openings **102**A, **102**B defined therein. More specifically, in this particular embodiment, the inner drive component **100**A has eight openings **102**A and the outer drive component **100**B has eight openings **102**B. The eight openings **102**A defined in the inner drive component **100**A are configured to receive the spring-loaded pins of an inner driven component of a proximal end of a coupleable tool (such as the pins **58**A of the inner driven component **60**A of the tool **50** discussed above, for example), while the eight openings **102**B defined in the outer drive component **100**B are configured to receive the spring-loaded pins of an outer driven component of a proximal end of a coupleable tool (such as the pins **58**B of the outer driven component **60**B of the tool **50** discussed above, for example). Alternatively, the coupler drive component **96** doesn't have two concentric drive components and instead has a single, unitary component and thus is configured to couple with the proximal end of a coupleable tool that also has a single, unitary component.

These openings **102**A, **102**B are defined in a predetermined pattern on the drive component **96** such that the pins **58**A, **58**B can fit into the openings **102**A, **102**B. In this embodiment, the inner drive component **100**A has twice as many openings **102**A as the number of pins **58**A on the inner driven component **60**A of the tool **50** and the outer drive component **100**B has twice as many openings **102**B as the number of pins **58**B on the outer driven component **60**B of the tool **50**. As such, the pins **58**A, **58**B can be positioned in the openings **102**A, **102**B in two different couplings (in two different sets of the openings **102**A, **102**B). As such, the fact that there are twice as many openings **102**A, **102**B as pins **58**A, **58**B further reduces the coupling time, as will be described in additional detail below.

In addition, this coupler **90** embodiment has a central tube **104** with a lumen **106** that is coupleable to any central tube of the tool to be coupled thereto (such as the tube **70** of the tool **50** described above). Alternatively, the coupler **90** does not have a central tube **104** when the tool to be coupled thereto has no central tube.

In use in which the tool **50** is coupled to the coupler **90**, the proximal end **54** of the tool body **52** is inserted into the coupler cavity **90** and urged proximally toward the coupler drive component **96**. While it is unlikely, if the pins **58**A, **58**B happen to be aligned correctly with the openings **102**A, **102**B without any rotation of either the tool **50** or the coupler **90** in relation to each other, the pins **58**A, **58**B will be urged into the openings **102**A, **102**B and disposed therein such that rotation of the inner drive component **100**A of the coupler drive component **96** will cause rotation of the inner driven component **60**A of the tool **50** and rotation of the outer drive component **100**B of the drive component **96** will cause rotation of the outer driven component **60**B of the tool **50**. In the more likely scenario that the pins **58**A, **58**B are not aligned correctly with the openings **102**A, **102**B, the pins **58**A, **58**B will make contact with the drive component **96** such that the pins **58**A, **58**B will be urged toward the device body **52** such that the pins **58**A, **58**B will be urged into their pin chambers **56**A, **56**B until the proximal end **54** contacts the coupler drive component **96**. At this point, the two drive components **100**A, **100**B of the drive component **96** are rotated in relation to the tool body **52** until the openings **102**A, **102**B are aligned correctly with the pins **58**A, **58**B. When the alignment is correct, the force mechanisms (not shown) coupled to each of the pins **58**A, **58**B will urge the pins proximally toward the coupler body **92**, thereby causing the pins **58**A, **58**B to be positioned in the openings **102**A, **102**B. Once the pins **58**A, **58**B are positioned correctly in the openings **102**A, **102**B, rotation of the inner drive component **100**A of the coupler drive component **96** will cause rotation of the inner driven component **60**A of the tool **50** and rotation of the outer drive component **100**B of the drive component **96** will cause rotation of the outer driven component **60**B of the tool **50**.

In accordance with one implementation, the coupler **90** having a drive component **96** with openings **102**A, **102**B makes it easier to sterilize the coupler **90** in comparison to pins (such as pins **58**A, **58**B), which can be more difficult to sterilize given the additional moving components, relative inaccessibility of some of those components, and related amount of surface area. However, in an alternative embodiment, the coupler (such as coupler **90**) could have spring-loaded pins and the tool (such as tool **50**) could have openings configured to receive those pins.

FIGS. **4**A and **4**B depict another device tool **120** that is a graspers tool **120** with suction and irrigation features and is coupled to a coupler **160**. More specifically, the tool body **126** is disposed within the cavity (not shown) of the coupler **160**. In this embodiment, the device tool **120** is an end effector **120** and the coupler **160** is coupled to or integral with the arm of a robotic device (not shown). The tool **120** has first and second grasper arms **122**A, **122**B that are configured to form the distal end of a lumen **124** when the two arms **122**A, **122**B are in their closed position as best shown in FIG. **4**A. As best shown in FIG. **4**B, the lumen **124** extends from the grasper arms **122**A, **122**B to the proximal end of the tool body **126** through a central tube **128**. The tube **128** is configured to transport irrigation fluid distally to the distal end of the tool **120** and apply suction proximally toward the proximal end of the body **126** through the lumen **124**.

As best shown in FIG. **4**B, the tool body **126** is made up of an outer driven component **130** and an inner driven component **132** having an inner lumen **134** with threads **136**. The tool **120** also has a push rod **138** that is disposed within the inner lumen **134** and extends distally from the lumen **134**. The push rod **138** has external threads **140** that mate with the threads **136** of the inner driven component **132**. In addition, the rod **138** is coupled at its distal end to the arm links **142**A, **142**B (wherein only the arm link **142**A is depicted in FIG. **4**B) that are coupled to the grasper arms **122**A, **122**B such that actuation of the push rod **138** causes actuation of the arms **122**A, **122**B to move between their open and closed configurations. The proximal end of the inner driven component **132** has two pin chambers **144**A, **144**B defined therein such that each chamber **144**A, **144**B contains a spring-loaded pin **146**A, **146**B that is configured to be extendable from the chamber **144**A, **144**B in the manner discussed above with respect to spring-loaded pins **58**A, **58**B. While two pin chambers **144**A, **144**B are depicted, it is understand that the inner driven component **132** can have additional chambers that are not visible in the cross-sectional view depicted in FIG. **4**B. As such, the inner driven component **132** can have a similar number of chambers as the inner driven component **60**A of the tool body **52** described above and shown in FIG. **2**B. In addition, the inner driven component **132** in this embodiment has an external channel **148** defined around an outer surface of the component **132**. The channel **148** is configured to receive two cylindrical pins (not shown) that are inserted through openings in the tool body **126** similar to the pins **62**A, **62**B positioned in the tool body **52** as shown in FIG. **2**A. These pins prevent the inner driven component **132** from moving laterally while allowing the component **132** to rotate.

The outer driven component **130** is rotatably disposed around the inner driven component **132** as best shown in FIG. **4**B and rotationally coupled to (or integral with) the yoke **150** as best shown in FIG. **4**A such that rotation of the outer driven component **130** causes rotation of the yoke **150**, thereby rotating the grasper arms **122**A, **122**B. The proximal end of the outer driven component **130** has two pin chambers **152**A, **152**B defined therein such that each chamber **152**A, **152**B contains a spring-loaded pin **154**A, **154**B that is configured to be extendable from the chamber **152**A, **152**B in the manner discussed above with respect to spring-loaded pins **58**A, **58**B. While two pin chambers **152**A, **152**B (and pins **154**A, **154**B) are depicted, it is understood that the outer driven component **130** can have additional chambers that are not visible in the cross-sectional view depicted in FIG. **4**B. As such, the outer driven component **130** can have a similar number of chambers (and pins) as the outer driven component **60**B of the tool body **52** described above and shown in FIG. **2**B.

As best shown in FIG. **4**B, in accordance with one embodiment, the coupler **160** has a coupler body **162** that contains the coupler drive component **164**. In this specific implementation, the coupler drive component **164** is made up of the inner drive component **164**A and the outer drive component **164**B. The inner drive component **164**A as shown has two pin-receiving openings **166**A, **166**B, each of which is configured to receive a corresponding spring-loaded pin as a result of the coupling action described above. More specifically, as shown in FIG. **4**B, pin **146**A is disposed in opening **166**A and pin **146**B is disposed in opening **166**B. While two openings **166**A, **166**B are depicted, it is understood that the inner drive component **164**A can have additional openings that are not visible in the cross-sectional view depicted in FIG. **4**B. As such, the inner drive component **164**A can have a similar number of openings as the inner drive component **100**A of the coupler drive component **96** described above and shown in FIG. **3**.

Further, the outer drive component **164**B as shown has two pin-receiving openings **168**A, **168**B, each of which is configured to receive a corresponding spring-loaded pin as a result of the coupling action described above. More specifically, as shown in FIG. **4**B, pin **154**A is disposed in opening **168**A and pin **154**B is disposed in opening **168**B. While two openings **168**A, **168**B are depicted, it is understood that the outer drive component **164**B can have additional openings that are not visible in the cross-sectional view depicted in FIG. **4**B. As such, the outer drive component **164**B can have a similar number of openings as the outer drive component **100**B of the coupler drive component **96** described above and shown in FIG. **3**.

In use, the inner drive component **164**A of the coupler **160** can be actuated to rotate. With the spring-loaded pins (including pins **146**A, **146**B) of the tool **120** disposed within the pin-receiving openings **166**A, **166**B of the inner drive component **164**A, the rotation of the inner drive component **164**A causes the inner driven component **132** to rotate. Because the internal threads **136** of the inner driven component **132** are mated with the external threads **140** of the push rod **138**, the rotation of the inner driven component **132** causes the push rod **138** to move laterally. Because the grasper arm **122**A, **122**B are coupled to the push rod **138** via the links **142**A, **142**B (wherein only **142**A is depicted in FIG. **4**B), the lateral movement of the push rod **138** causes the grasper arms **122**A, **122**B to move between their open and closed configurations.

Further, the outer drive component **164**B can also be actuated to rotate. With the spring-loaded pins (including pins **154**A, **154**B) of the tool **120** disposed within the pin-receiving openings **168**A, **168**B of the outer drive component **164**B, the rotation of the outer drive component **164**B causes the outer driven component **130** to rotate. Because the yoke **150** is coupled to or integral with the distal end of the outer driven component **130** (as best shown in FIG. **4**A), the rotation of the outer driven component **130** causes the yoke **150** to rotate. Because the grasper arms **122**A, **122**B are disposed at least partially within the yoke **150** and are rotationally constrained by the yoke **150**, the rotation of the yoke **150** causes the grasper arms **122**A, **122**B to rotate around the same axis.

FIGS. **5**A and **5**B depict another embodiment of a coupler **180** coupled to a tool **230**, wherein the coupler **180** and tool **230** are configured such that the tool **230** can have bipolar capabilities as will be described below. FIG. **5**A depicts the coupler **180** without the tool **230** coupled thereto, while FIG. **5**B depicts the coupler **180** and tool **230** coupled together. In this implementation, the coupler **180** and the tool **230** have components and features substantially similar to those described above and depicted in FIGS. **4**A and **4**B with respect to the coupler **160** and tool **120**, except for those differences described herein.

In this embodiment, the coupler **180** is coupled to or integral with the distal end of a forearm of a robotic surgical device (not shown). Alternatively, the coupler **180** can be coupled to or integral with any medical device to which a tool (such as tool **230**) is to be coupled. The coupler **180** has a coupler body **182** that has an actuable locking ring **186** disposed within the coupler cavity **184**. Further, the body **182** has a central tube **188** that defines a central lumen **190**, an inner drive component **192**, an outer drive component **194**, and an insulation layer **196** disposed between the inner and outer drive components **192**, **194**, thereby electrically separating the inner and outer drive components **192**, **194** to provide for potential bipolar capabilities.

The actuable locking ring **186** can be used to retain or lock the tool **230** in place in the coupler **180** in the following manner. The cavity **184** in this implementation has a narrow portion (or "wall protrusion") **212** defined in the inner wall **210** of the cavity **184**. Further, the inner wall **210** also has a wider portion (or "channel") **214** defined in the inner wall proximal to the wall protrusion **212**. The actuable locking ring **186** has a corresponding external ring protrusion (also referred to herein as a "fin") **218** extending from an outer wall **216** of the ring **186**. In certain embodiments, as the actuable locking ring **186** is moved laterally within the cavity **184**, the position of the ring fin **218** in relation to the inner wall channel **214** and the wall protrusion **212** can directly influence the inner diameter of the ring **186**. That is, if the ring **186** is disposed within the cavity **184** such that the fin **218** is disposed in the channel **214**, the ring **186** has a relatively larger inner diameter. However, if the ring **186** is moved distally within the cavity **184** such that the fin **218** is moved toward the wall protrusion **212**, the fin **218** will be urged radially inward, thereby causing the inner diameter of the ring **186** to become smaller. As such, the interaction between the locking ring **186** and the inner wall of the cavity **184** when the locking ring **186** is moved between a locked and an unlocked position causes the inner diameter of the locking ring **186** to be altered, thereby either increasing or reducing the contact friction between the inner wall **220** of the ring **186** and any tool body (such as tool body **232**) disposed therein.

Further, the actuable locking ring **186** can also have coupling blades (not shown) disposed along the inner wall **220** of the ring **186** that are configured to enhance the retention of the tool body within the cavity **184** when the inner wall **220** is in contact with the tool body **232**. Alternatively, any component or feature can be used that can help to maintain the physical coupling or frictional retention between the inner wall **220** of the ring **186** and the tool body **232**.

In use according to one embodiment as best shown in FIG. **1A-1C** in combination with FIGS. **5**A and **5**B, when the locking ring (such as ring **186**) is in the locked position as best shown with locking ring **22** in FIG. **1**A, the ring fin **218** is disposed adjacent to and in contact with the wall protrusion **212**, thereby resulting in a smaller inner diameter of the ring **186** and thus increased contact between the inner wall **220** of the ring **186** and the tool body (such as tool body **30** or tool body **232**) disposed therein. This increased contact, along with any retention feature on the inner wall **220** (such as, for example, the retention blades discussed above), results in the tool body (such as body **30** or body **232**) being locked or otherwise retained in the coupler **180** (or coupler **12**) by the locking ring **186** (or ring **22**). Further, as a result of the configuration of the inner wall **210** of the cavity **184** and the configuration of the ring **186**, any distal force applied to the tool body **30**, **180** will also urge the ring **186** distally as a result of the contact friction between the body **30**, **180** and the ring **186**, thereby increasing the contact friction between the ring **186** and the body **30**, **180**. That is, the configuration of the cavity **184** and ring **186** is such that any distal force applied to the tool body **30**, **180** actually increases the strength of the locking mechanism.

When the locking ring (such as ring **186**) is urged into the unlocked position as best shown in FIGS. **1**B and **1**C (with respect to ring **22**) and FIGS. **5**A and **5**B (with respect to ring **186**, the ring fin **218** is disposed in the channel **214**, thereby resulting in a larger inner diameter of the ring **186** (by comparison with the ring **186** in the locked position) and thus decreased (or no) contact between the inner wall **220** of the ring **186** and the tool body (such as tool body **30** or tool body **232**) disposed therein. This reduction or elimination of contact results in the tool body (such as body **30** or body **232**) being removable from the coupler **180** (or coupler **12**).

In this embodiment as shown in FIGS. **5**A and **5**B, the outer drive component **194** is supplied with an electrical connection via a first electrical contact (also called a "spring pin") **234** that is configured to maintain contact with the drive component **194** while the component **194** is rotating. That is, the spring pin **234** is positioned in the coupler **180** such that it remains in contact with the drive component **194** even when the drive component **194** is actuated to rotate. Further, the spring pin **234** has a force mechanism **238**—in this case, a compression spring—that urges the spring pin **234** toward the drive component **194**, thereby further ensuring that contact is maintained.

The insulation layer **196** is positioned between the inner drive component **192** and the outer drive component **194** such that the insulation layer **196** electrically isolates the two drive components **192**, **194** from each other. The electrical isolation results in two independent electrical conduction paths to any tool (such as tool **230**) coupled to the coupler **180** for potential bipolar capability.

According to the embodiment depicted, the inner drive component **192** is supported by two bearings **240**, **242**. Further, the coupler **180** has a second electrical contact (also called a "spring pin") **244** disposed between the two bearings **240**, **242** that is in contact with the inner drive component **192**. The second spring pin **244** has a force mechanism **246**—in this case, a compression spring—that urges the spring pin **244** toward the drive component **192**, thereby further ensuring that contact is maintained. As such, the second spring pin **244** provides the second independent electrical source for the tool (such as tool **230**) coupled to the coupler **180**. Further, the coupler **180** also has a retaining ring **248** that is positioned in the coupler **180** such that it constrains the inner drive component **192** from translating laterally.

In this implementation, the central tube **188** can be used for suction/irrigation, drug delivery, tool delivery, clip application, and/or other known functions or procedures.

In alternative embodiments, the coupler can provide only one electrical connection (instead of two), thereby eliminating the need for electrical isolation and insulation between components. In further alternatives, the coupler can have three or more electrical connections to provide three or more separate, independent electrical sources for three different uses in the tool (such as tool **230**).

The coupler embodiments discussed above have included two drive components (an inner drive component and an outer drive component). Alternative coupler embodiments could have three or more drive components. In further alternatives, a coupler embodiment could have one drive component.

The various coupler embodiments disclosed herein can be utilized to simplify various surgical procedures. For example, in those implementations in which medical device is a robotic surgical device, a quick-change coupler on an arm of the surgical device could allow for exchanging end effectors while the arm of the device is positioned within a cavity of the patient. In one such situation, a separate device having at least one additional end effector positioned thereon is positioned in the patient's cavity and operates in conjunction with the device arm and coupler to effect the exchange of one end effector for another on the arm. Alternatively, a separate external device can be inserted into the patient's cavity through a separate or auxiliary port and/or trocar and operates to remove or un-install the end effector from the arm of the robotic device and retract it from the cavity. The new end effector is then attached to the external tool, the tool is re-inserted into the cavity, and the tool operates in conjunction with the device arm to install or attach the new end effector to the coupler.

Although the various implementations herein been described with reference to preferred embodiments, persons skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the inventions.

What is claimed is:

1. A coupling apparatus for a medical device, the apparatus comprising:
- (a) a coupler body;
- (b) a cavity defined in a distal end of the coupler body;
- (c) a rotatable drive component disposed within the cavity, the drive component comprising:
  - (i) an inner drive component comprising at least two inner pin-receiving openings; and
  - (ii) an outer drive component comprising at least two outer pin-receiving openings; and
- (d) an actuable locking ring disposed around the cavity.

2. The coupling apparatus of claim **1**, wherein the coupler body is coupleable to a tool, wherein the tool comprises:
- (a) a tool body sized and arranged to be positionable within the cavity;
- (b) a rotatable driven component operably coupled to the tool body, the rotatable driven component comprising:
  - (i) at least two pin chambers defined in the rotatable driven component; and
  - (ii) at least two tensioned pins, wherein each of the at least two tensioned pins is disposed within and is extendable from one of the at least two pin chambers comprising at least two tensioned pins extending therefrom,

wherein the rotatable driven component is alignable with the rotatable drive component such that the at least two tensioned pins extend into the at least two pin-receiving openings.

3. The coupling apparatus of claim **1**, wherein the coupler body is coupleable to a tool, wherein the tool comprises:
- (a) a tool body sized and arranged to be positionable within the cavity; and
- (b) a rotatable driven component operably coupled to the tool body, the rotatable driven component comprising:
  - (i) an inner driven component comprising at least two inner pin chambers defined in the inner driven component and at least two inner tensioned pins disposed within and extendable from the at least two inner pin chambers; and
  - (ii) an outer driven component comprising at least two outer pin chambers defined in the outer driven component and at least two outer tensioned pins disposed within and extendable from the at least two outer pin chambers;

wherein the inner driven component is alignable with the inner drive component such that the at least two inner tensioned pins extend into the at least two inner pin-receiving openings, and

wherein the outer driven component is alignable with the outer drive component such that the at least two outer tensioned pins extend into the at least two outer pin-receiving openings.

4. The coupling apparatus of claim **1**, further comprising an insulation layer disposed between the inner and outer drive components.

5. A coupling apparatus for a medical device, the apparatus comprising:
- (a) a coupler body;
- (b) a cavity defined in a distal end of the coupler body;
- (c) a rotatable drive component disposed within the cavity, the drive component comprising at least two pin-receiving openings; and
- (d) an actuable locking ring disposed around the cavity, wherein the actuable locking ring is movable between a depressed position in which any tool body disposed within the cavity is releasable and a non-depressed position in which any tool body disposed within the cavity is locked therein.

6. The coupling apparatus of claim **5**, wherein the coupler body is coupleable to a tool, wherein the tool comprises:
- (a) a tool body sized and arranged to be positionable within the cavity;
- (b) a rotatable driven component operably coupled to the tool body, the rotatable driven component comprising:
  - (i) at least two pin chambers defined in the rotatable driven component; and
  - (ii) at least two tensioned pins, wherein each of the at least two tensioned pins is disposed within and is extendable from one of the at least two pin chambers comprising at least two tensioned pins extending therefrom,

wherein the rotatable driven component is alignable with the rotatable drive component such that the at least two tensioned pins extend into the at least two pin-receiving openings.

7. The coupling apparatus of claim **5**, wherein the rotatable drive component comprises:
- (a) an inner drive component comprising at least two inner pin-receiving openings; and
- (b) an outer drive component comprising at least two outer pin-receiving openings.

8. The coupling apparatus of claim **7**, wherein the coupler body is coupleable to a tool, wherein the tool comprises:
- (a) a tool body sized and arranged to be positionable within the cavity; and

(b) a rotatable driven component operably coupled to the tool body, the rotatable driven component comprising:

(i) an inner driven component comprising at least two inner pin chambers defined in the inner driven component and at least two inner tensioned pins disposed within and extendable from the at least two inner pin chambers; and

(ii) an outer driven component comprising at least two outer pin chambers defined in the outer driven component and at least two outer tensioned pins disposed within and extendable from the at least two outer pin chambers;

wherein the inner driven component is alignable with the inner drive component such that the at least two inner tensioned pins extend into the at least two inner pin-receiving openings, and

wherein the outer driven component is alignable with the outer drive component such that the at least two outer tensioned pins extend into the at least two outer pin-receiving openings.

9. The coupling apparatus of claim **7**, further comprising an insulation layer disposed between the inner and outer drive components.

10. The coupling apparatus of claim **1**, further comprising an elongate tube disposed through a length of the coupler body such that the rotatable drive component is disposed around a distal portion of the elongate tube, the elongate tube comprising a lumen in fluid communication with a distal opening of the elongate tube.

11. A coupling system for a medical device, the system comprising:

(a) a coupling apparatus associated with the medical device, the apparatus comprising:

(i) a coupler body;

(ii) a cavity defined in a distal end of the coupler body;

(iii) a rotatable drive component disposed within the cavity, the drive component comprising at least two pin-receiving openings; and

(iv) an actuable locking ring disposed around the cavity; and

(b) a tool body coupleable with the coupling apparatus, wherein the tool body is sized and arranged to be positionable within the cavity, the tool body comprising:

(i) a rotatable driven component operably coupled to the tool body, the rotatable driven component comprising:

(A) at least two pin chambers defined in the rotatable driven component; and

(B) at least two tensioned pins disposed within and extendable from the at least two pin chambers,

wherein the rotatable driven component is alignable with the rotatable drive component such that the at least two tensioned pins extend into the at least two pin-receiving openings.

12. The coupling system of claim **11**, wherein the rotatable drive component comprises:

(a) an inner drive component comprising at least two inner pin-receiving openings; and

(b) an outer drive component comprising at least two outer pin-receiving openings.

13. The coupling system of claim **12**, wherein the rotatable driven component comprises:

(a) a rotatable inner driven component, wherein the at least two pin chambers comprise at least two inner pin chambers defined in the rotatable inner driven component, and wherein the at least two tensioned pins comprise at least two inner tensioned pins disposed within and extendable from the at least two inner pin chambers; and

(b) a rotatable outer driven component, wherein the at least two pin chambers comprise at least two outer pin chambers defined in the rotatable outer driven component, and wherein the at least two tensioned pins comprise at least two outer tensioned pins disposed within and extendable from the at least two outer pin chambers

wherein the rotatable inner driven component is alignable with the inner drive component such that the at least two inner tensioned pins extend into the at least two inner pin-receiving openings, and

wherein the rotatable outer driven component is alignable with the outer drive component such that the at least two outer tensioned pins extend into the at least two outer pin-receiving openings.

14. The coupling system of claim **12**, further comprising an insulation layer disposed between the inner and outer drive components.

15. The coupling system of claim **11**, wherein the actuable locking ring is movable between a depressed position in which the tool body is releasable from the cavity and a non-depressed position in which the tool body disposed within the cavity is locked therein.

16. The coupling system of claim **11**, further comprising an elongate tube disposed through a length of the coupler body such that the rotatable drive component is disposed around a distal portion of the elongate tube, the elongate tube comprising a lumen in fluid communication with a distal opening of the elongate tube.

17. A coupling system for a medical device, the system comprising:

(a) a coupling apparatus associated with the medical device, the apparatus comprising:

(i) a coupler body;

(ii) a cavity defined in a distal end of the coupler body;

(iii) an inner drive component comprising at least two inner pin-receiving openings;

(iv) an outer drive component comprising at least two outer pin-receiving openings; and

(v) an actuable locking ring disposed around the cavity; and

(b) a tool body coupleable with the coupling apparatus, wherein the tool body is sized and arranged to be positionable within the cavity, the tool body comprising:

(i) a rotatable inner driven component comprising:

(A) at least two inner pin chambers defined in the rotatable inner driven component, and

(B) at least two inner tensioned pins disposed within and extendable from the at least two inner pin chambers; and

(ii) a rotatable outer driven component comprising:

(A) at least two outer pin chambers defined in the rotatable outer driven component; and

(B) at least two outer tensioned pins disposed within and extendable from the at least two outer pin chambers,

wherein the rotatable inner driven component is alignable with the inner drive component such that the at least two inner tensioned pins extend into the at least two inner pin-receiving openings, and

wherein the rotatable outer driven component is alignable with the outer drive component such that the at least two outer tensioned pins extend into the at least two outer pin-receiving openings.

18. The coupling system of claim **17**, further comprising an insulation layer disposed between the inner and outer drive components.

19. The coupling system of claim **17**, wherein the actuable locking ring is movable between a depressed position in which the tool body is releasable from the cavity and a non-depressed position in which the tool body disposed within the cavity is locked therein.

20. The coupling system of claim **17**, further comprising an elongate tube disposed through a length of the coupler body such that the rotatable drive component is disposed around a distal portion of the elongate tube, the elongate tube comprising a lumen in fluid communication with a distal opening of the elongate tube.

* * * * *