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NIC



Building Cryogenic Targets with a Precision Reconfigurable Assembly Station

**19th Target Fabricators Conference
Feb 21-26, 2010**

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Lawrence Livermore National Laboratory • National Ignition Campaign

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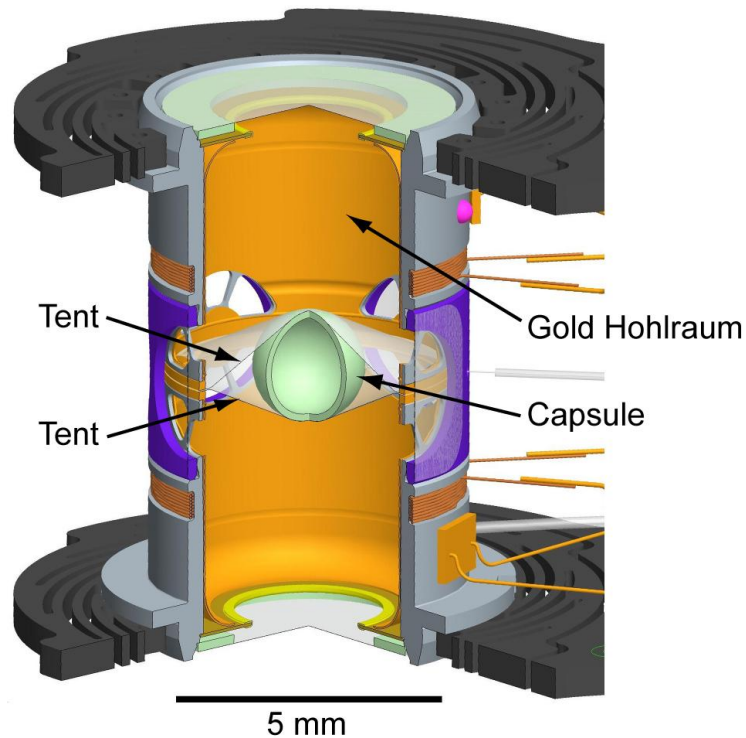
Introduction

- **A reconfigurable assembly station was developed for assembling ICF cryogenic targets that have been and will be fielded at NIF**
- **Various configurations of the machine were explored and used to build cryogenic ICF targets:**
 - **Symmetry Capsules targets**
 - **Convergent Ablator targets**
 - **Keyhole targets**
- **Tooling and target fabrication processes required for these targets was developed**

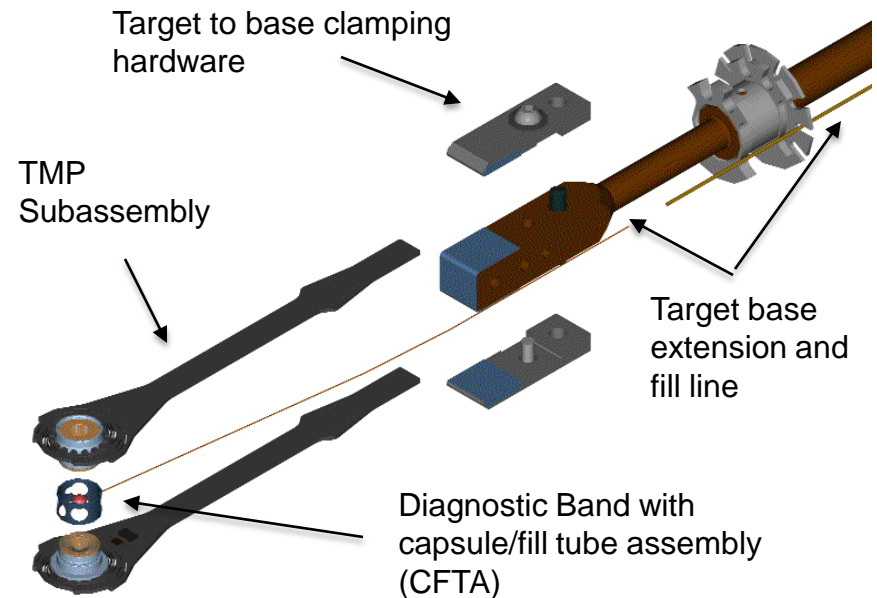
NIC Cryogenic Target

- The NIC targets are designed so that the physics package (hohlraum, capsule and the gas between them) can be tailored independently of the thermal-mechanical package (TMP) that holds it (TMP-halves, diagnostic band, and silicon cooling arms). The required position accuracy of the assembled target components is in the range of 2-20 μm .

Model of a NIC target



Model showing target components at final assembly step.



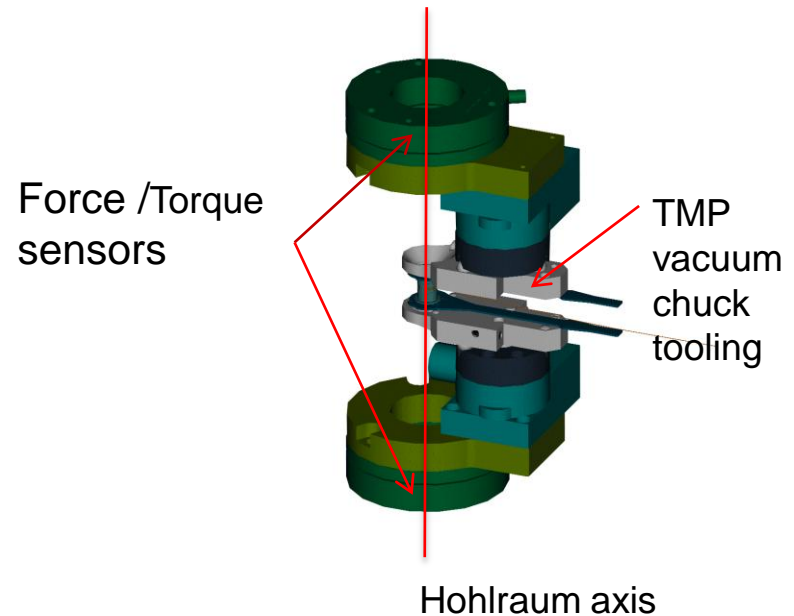
Flexible Final Assembly Machine

- The assembly station, referred to as FlexFAM is a companion system to the earlier Final Assembly Machine (FAM). Both machines consist of a manipulator system that uses force and torque feedback, integrated with an optical coordinate measuring machine (OCMM) that provides real-time dimensional metrology.

Flexible Final Assembly Machine



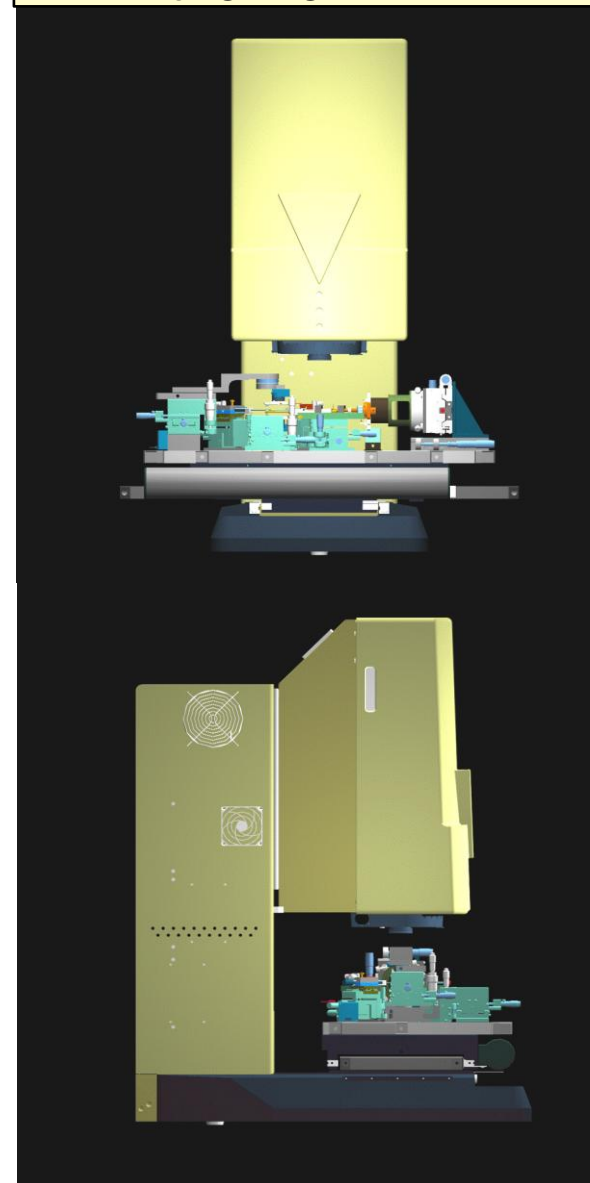
Model showing configuration of the TMP tooling and force/torque sensors



Overview of the Design

- The OCMM's vision system and through-the-lens (TTL) laser-based height measuring probe provide micron-level measurement accuracy over a working volume of 30 cm x 15 cm x 20 cm.
- The manipulator system resides on a platform that can be readily removed and replaced from the OCMM.
- The FlexFAM was designed to operate in a class 100 clean room.

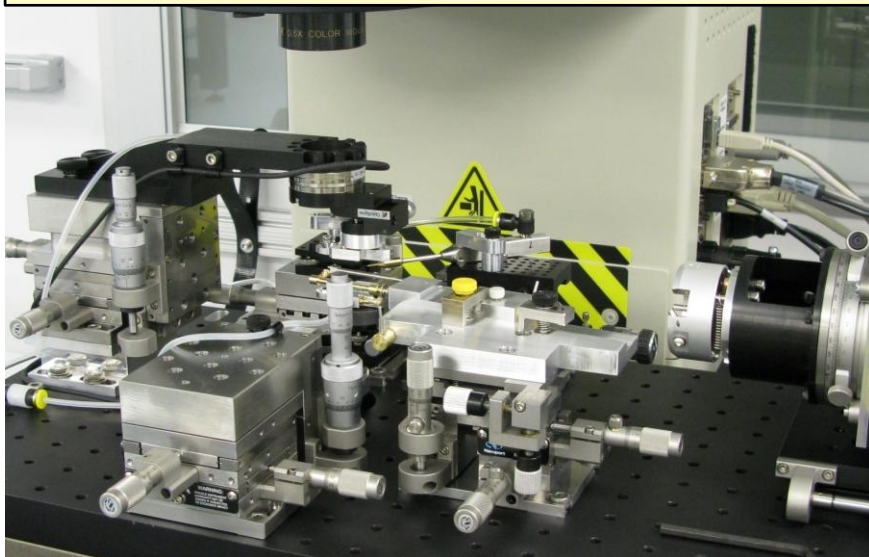
Front and side view of the FlexFAM



Compact Design

- The smaller envelope of the FlexFAM manipulator system allowed integrating it with a smaller bench-top styled OCMM, providing easier operator access to the target assembly work zone. All of the stages are within comfortable reach of the operator so the need for motorized stages was greatly reduced.

Closup of manipulator system



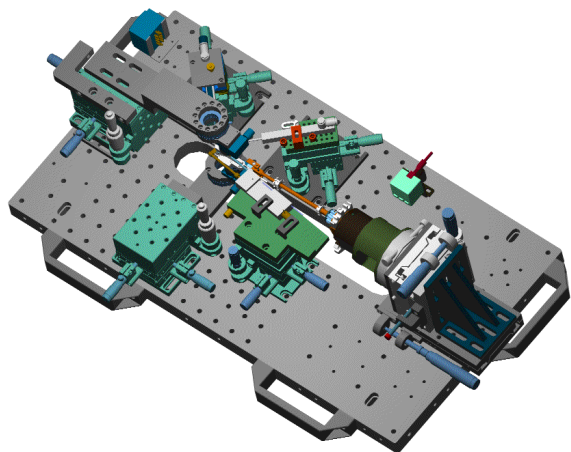
Target assembly technician operating the FlexFAM



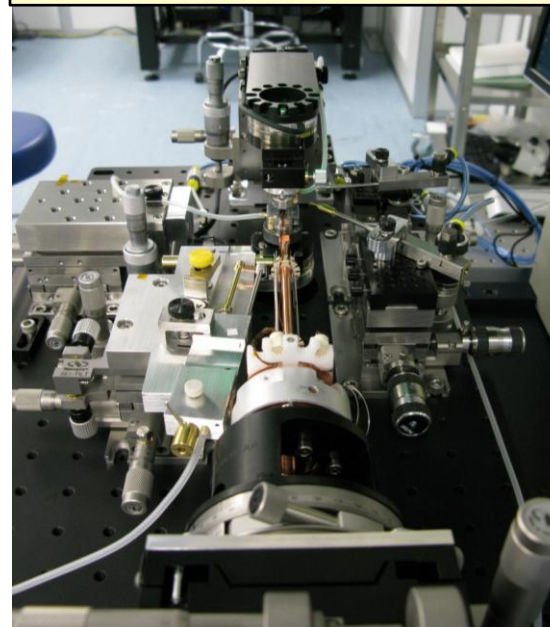
Reconfigurable Manipulator System

- The manipulator system consists of an arrangement of mechanical stages and tooling that are configured to provide the necessary degrees of motion freedom for the subassemblies and components needed to manufacture a particular type of target.
- The system consists entirely of manually-actuated stages, which enabled a quick path to developing a thirty degrees-of-freedom motion system that is compact and simple to operate.

Model of manipulator system



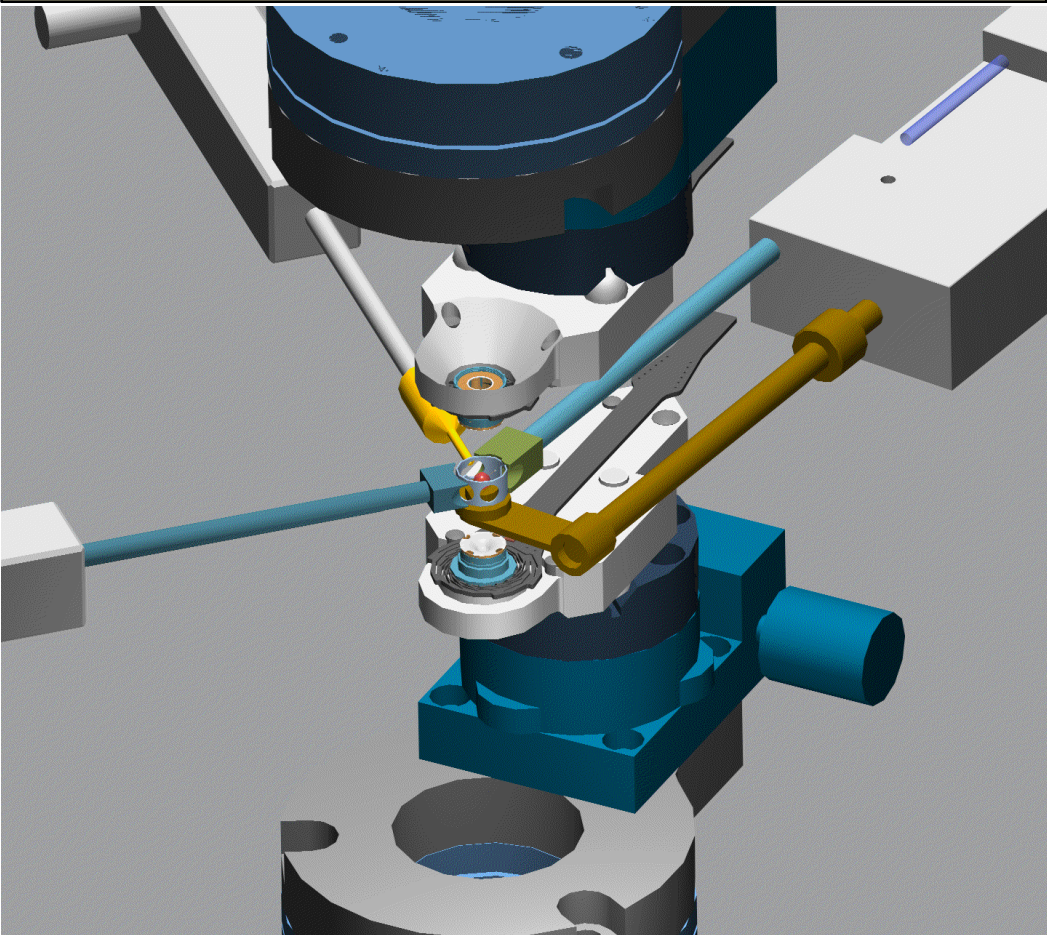
FlexFAM manipulators



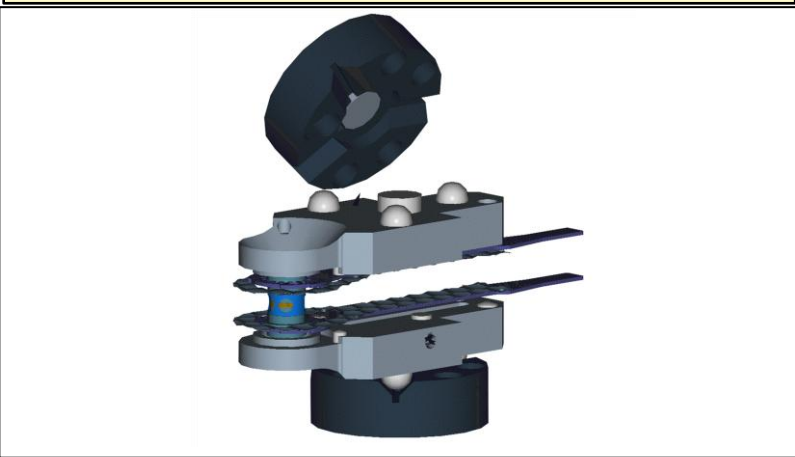
Tooling and Fixtures

- Target components are held by LLNL-developed vacuum tooling and specialized fixtures.
- Incorporated in the FlexFAM tooling are kinematic and semi-kinematic mounts that ensure accurate and repeatable remove-and-replace orientation of the tooling.

Closup of vacuum tooling used to hold target components.

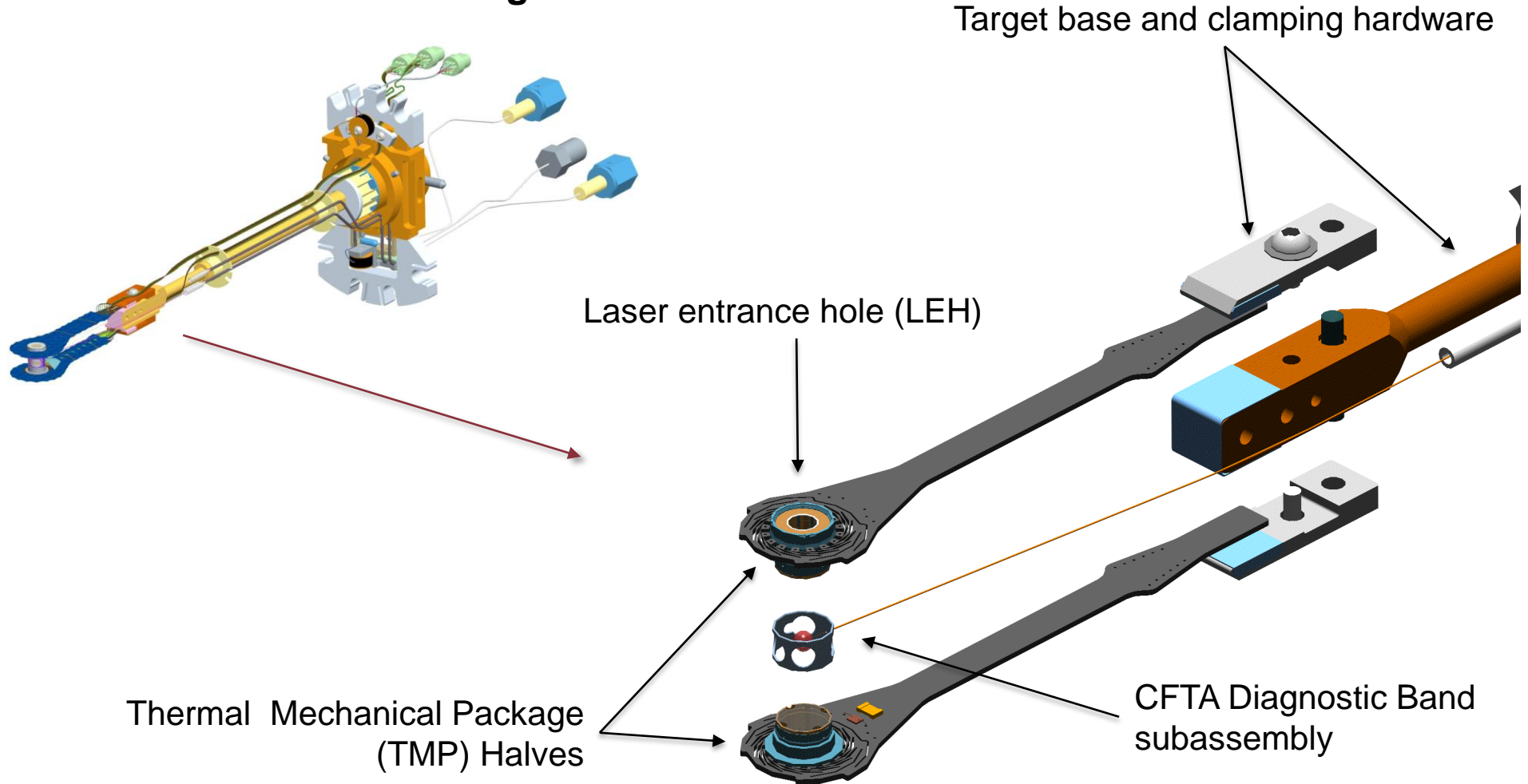


Model of Kinematic magnetic mount



Assembling NIC Targets (Symmetry Capsules)

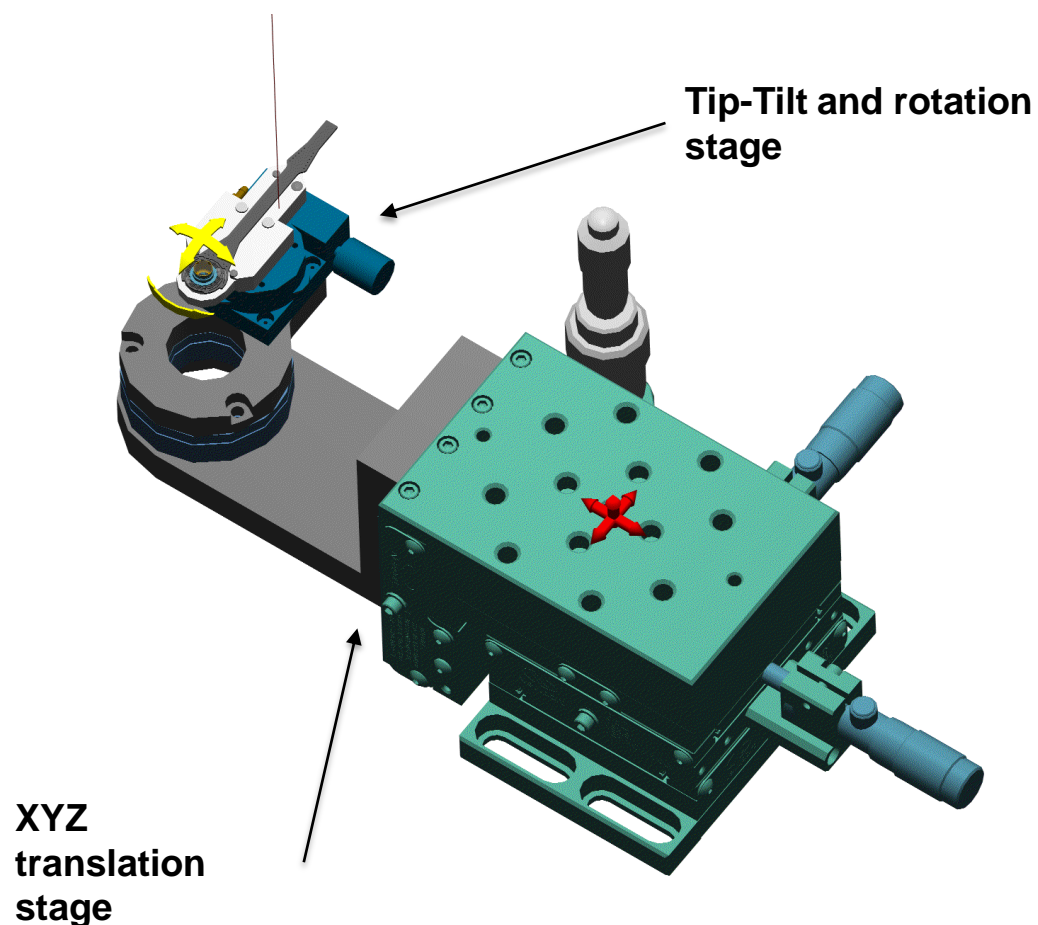
- **NIC Production Target**



Orientation of Target Components

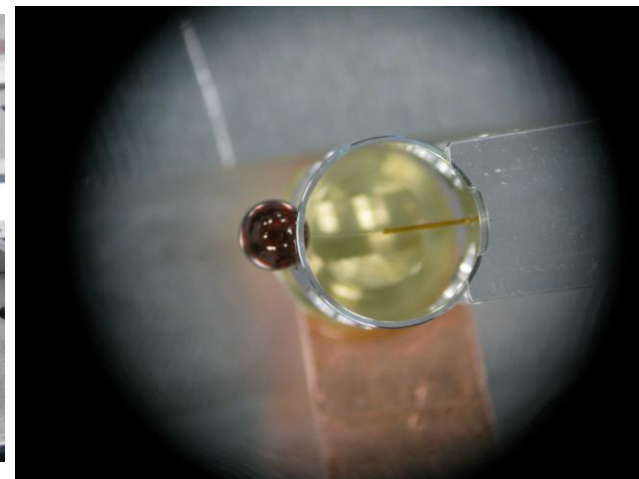
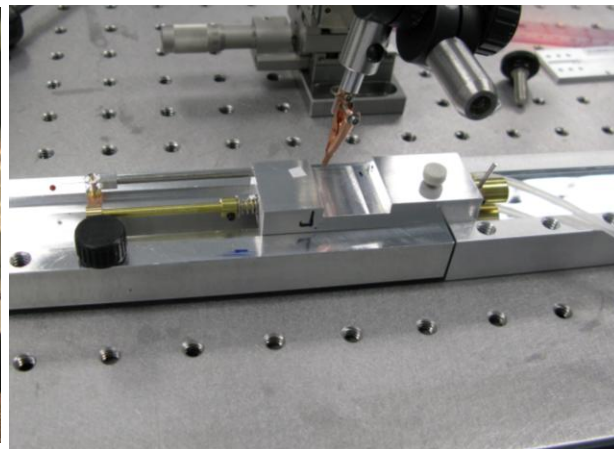
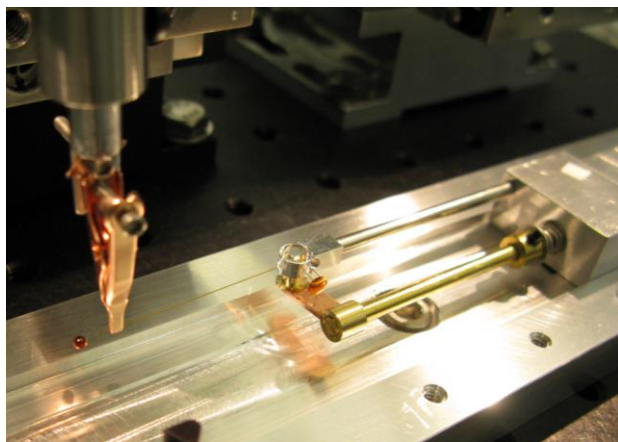
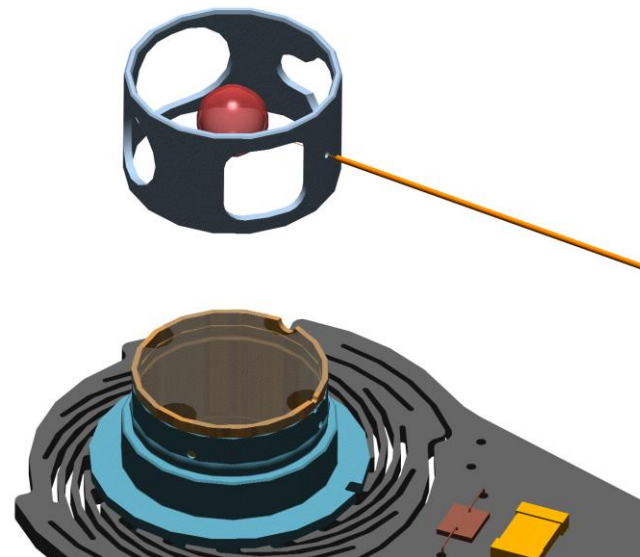
- Subassembly orientation is required due to tolerance stack up and component loading errors.
- The vision system and laser probe of the OCMM are used to guide and align the target components and tooling. Measurement of the relative position and orientation of the components is also provided..

Closup of precision translation stages used to orientate target components.



Capsule fill-tube assembly (CFTA) and diagnostic band transfer

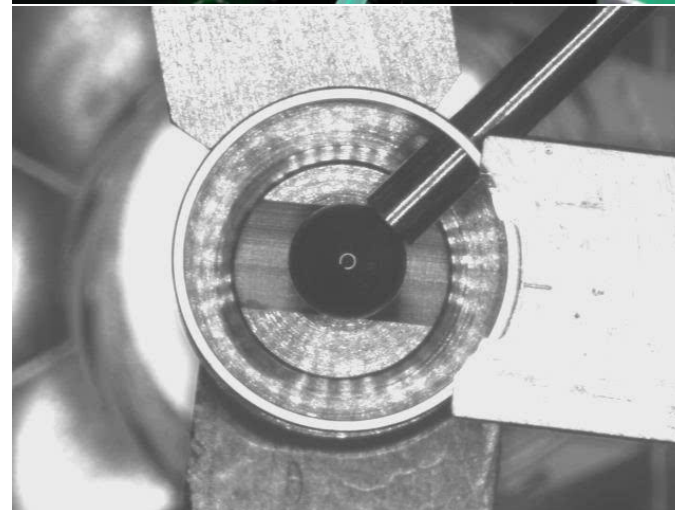
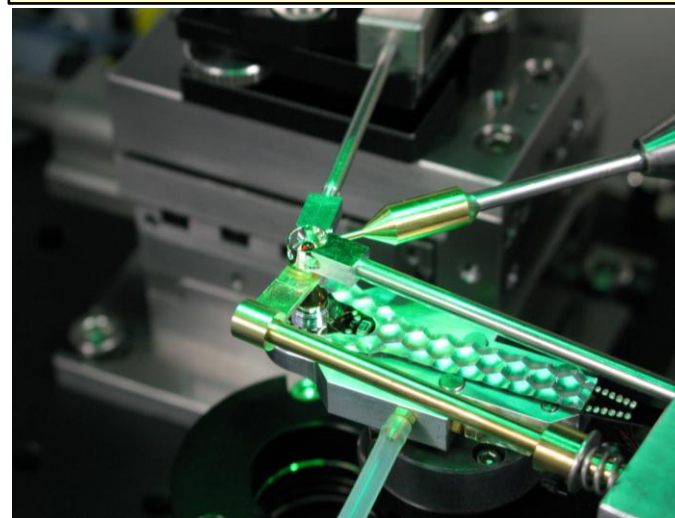
- The capsule fill-tube assembly is pre-threaded into the diagnostic band before the two items reach the FlexFAM
- The CFTA is unpacked from the shipping container and threaded through the diagnostic band held by the CFTA transfer tooling.



CFTA loaded on FLEXFAM

- The CFTA / Diagnostic band is then placed on the assembly station and secured to a 5 degrees of freedom (DOF) translation stage.
- The CFTA diagnostic band subassembly is then transferred to the capsule positioning chuck and FFAM diagnostic band chuck.
- The transfer tooling is withdrawn inline with the capsule fill-tube, clearing the TMP halves and providing support of the fill tube.

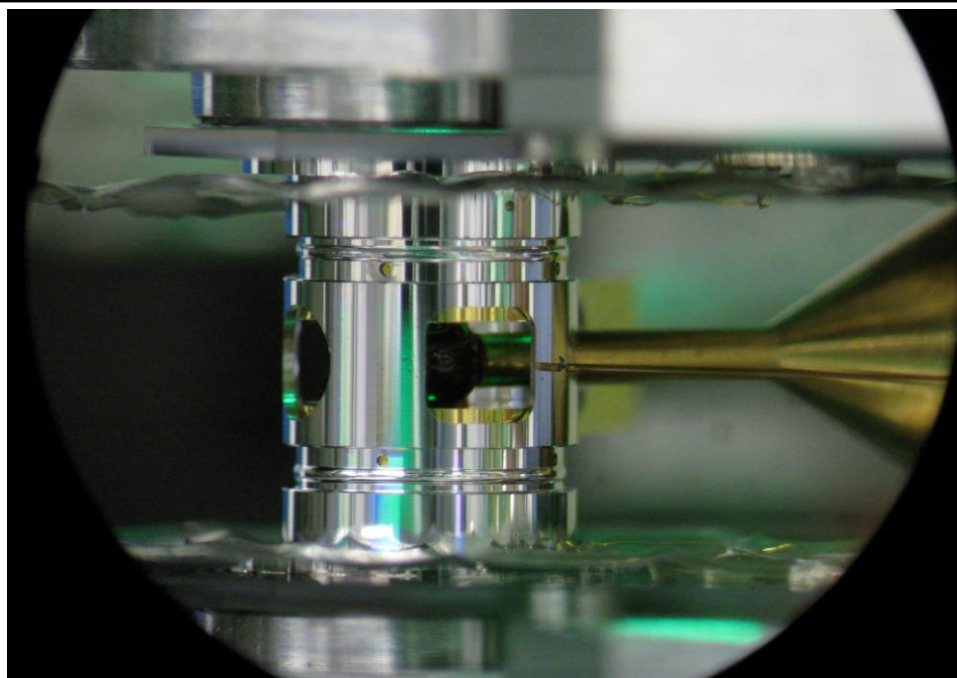
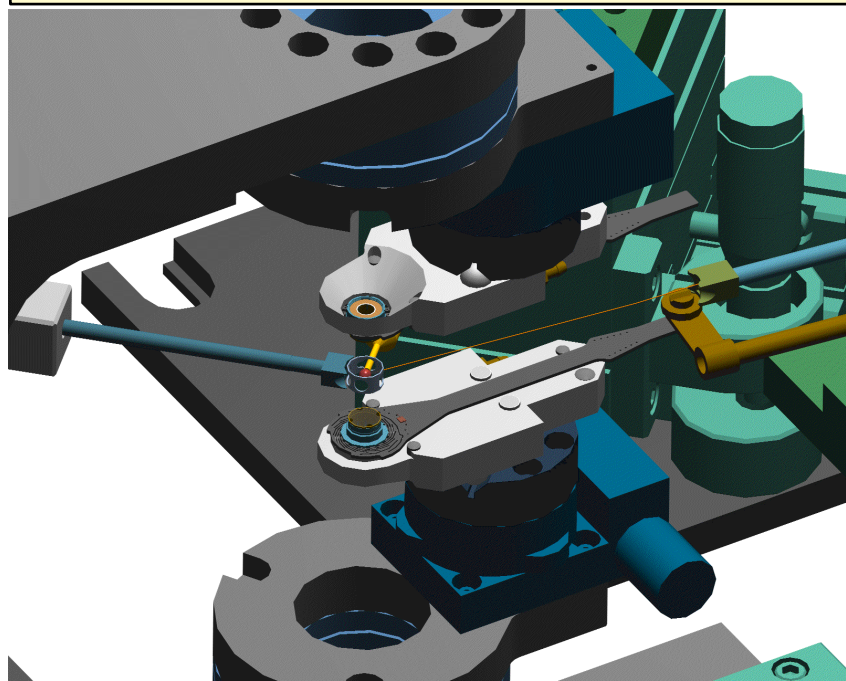
Photos showing the CFTA diagnostic band transfer tools



Tenting the Capsule

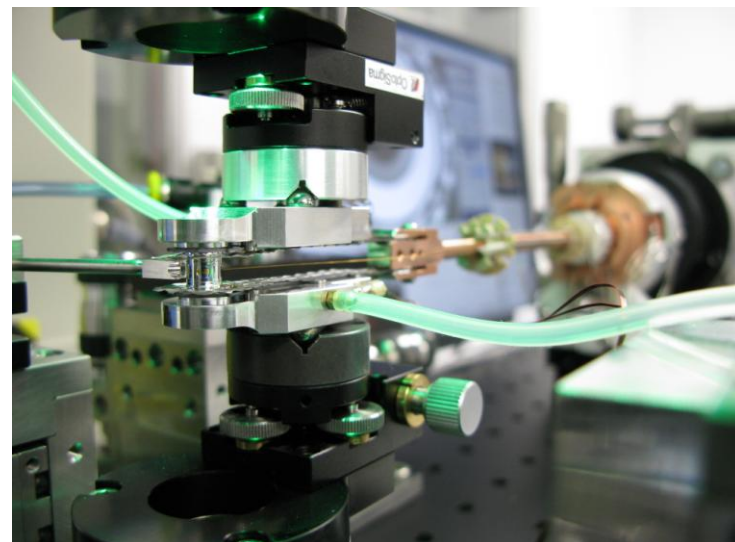
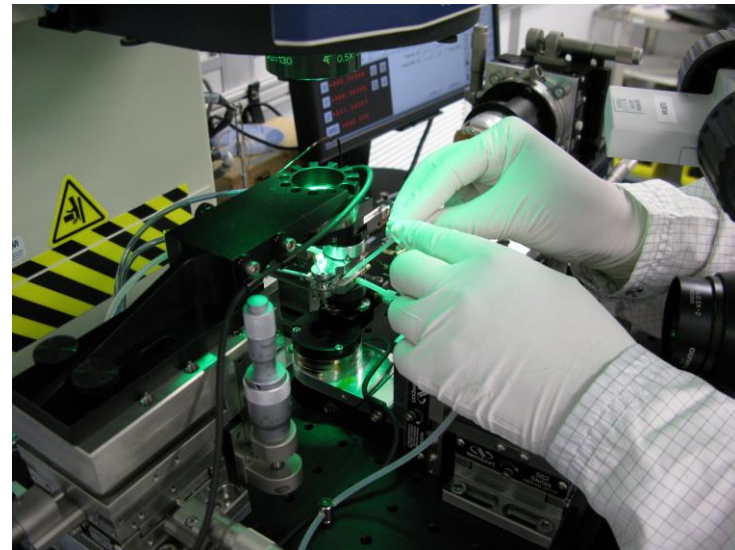
- The two halves are then simultaneously adjusted to bring the two TMP-halves together to mate with the diagnostic band and tent the capsule.

Model and photo of tenting operation



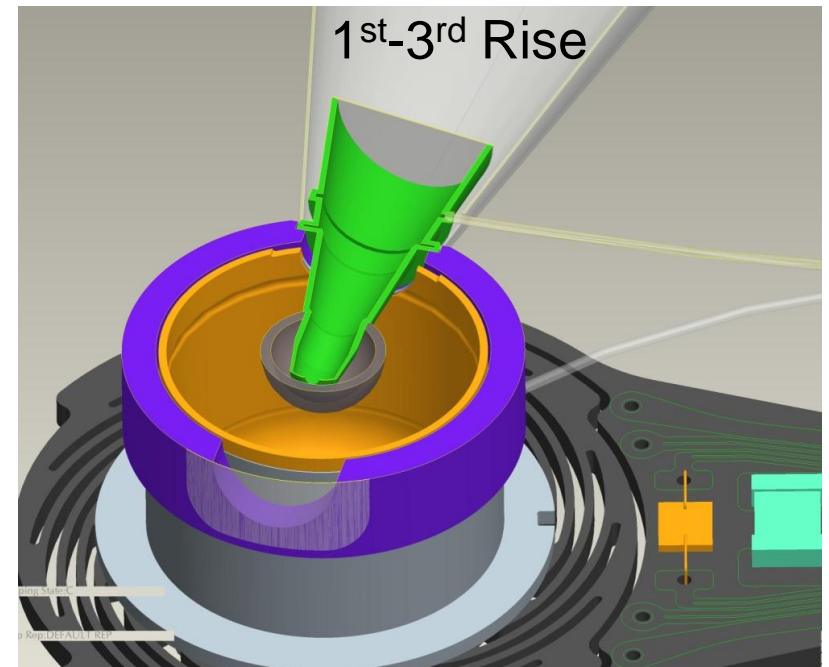
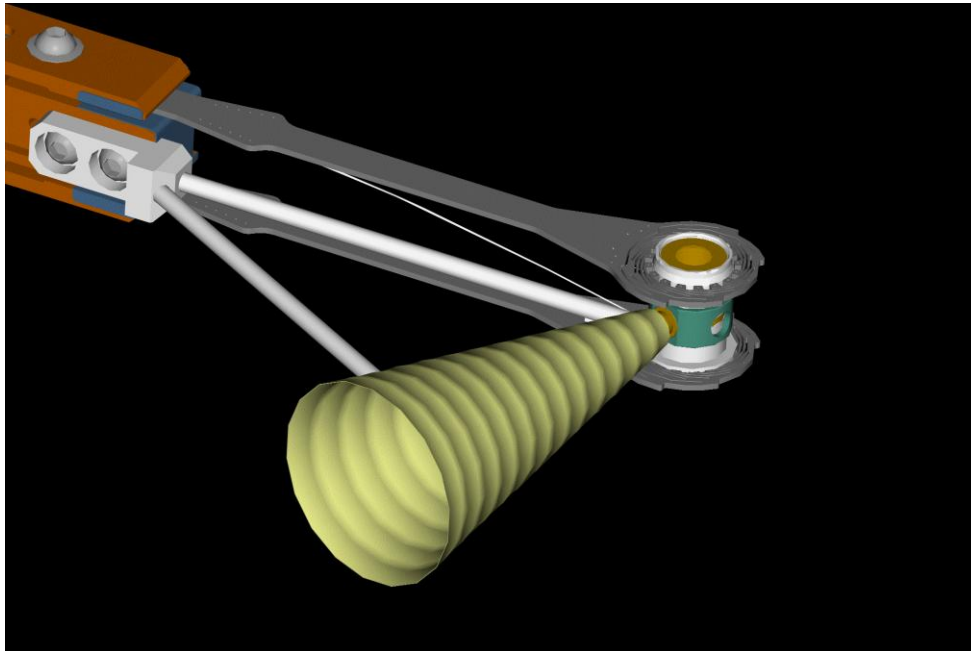
Completing the assembly.

- The capsule fill-tube and TMP-halves are adhesively tacked to the diagnostic band.
- The target base is then attached to the target assembly using mechanical clamps.
- The assembled target is then released from the FlexFAM and packaged for further processing.



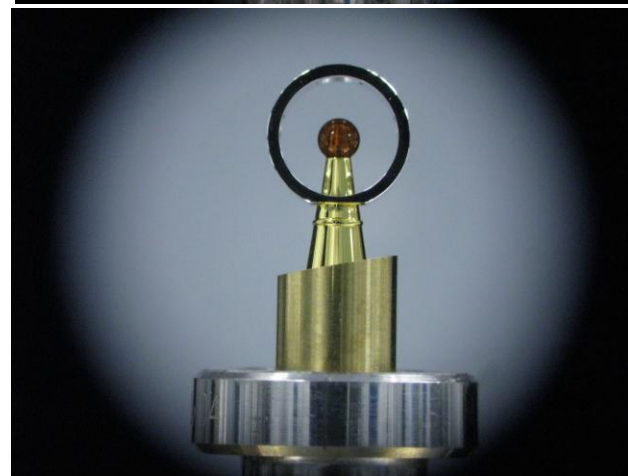
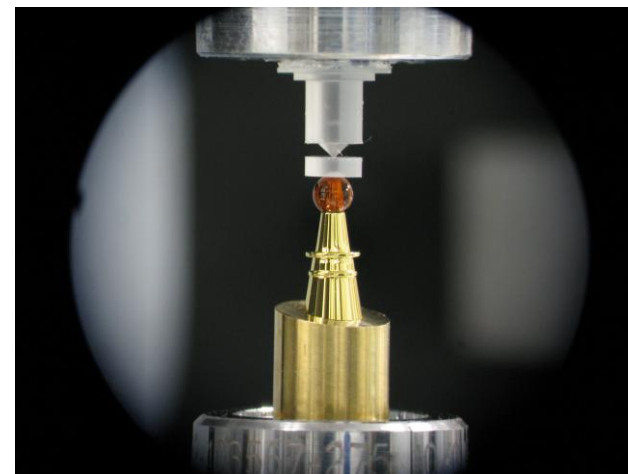
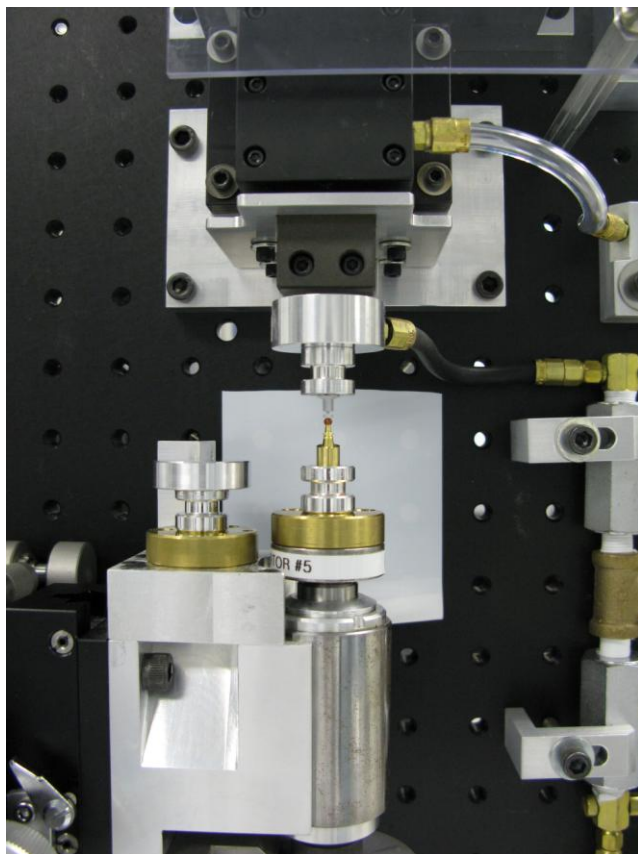
Keyhole

- The Keyhole target uses a cone-in-capsule design for shock timing experiments.



Key Hole Subassembly

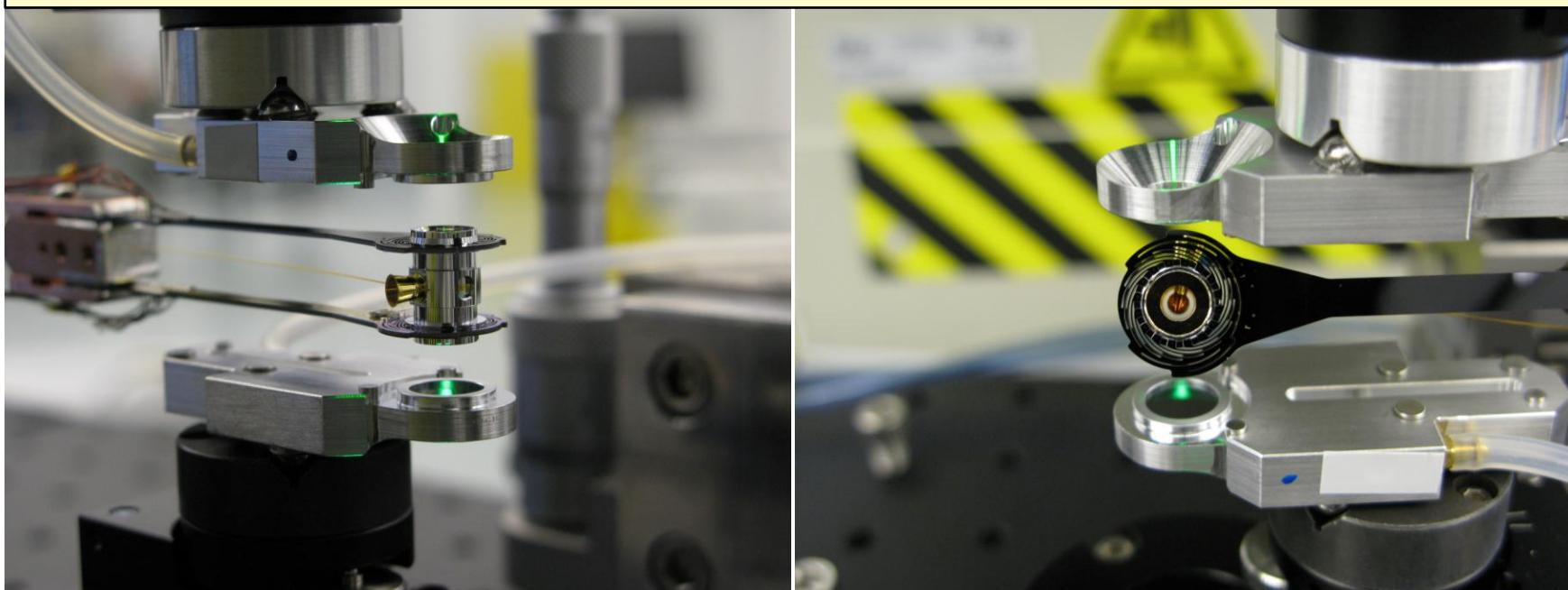
- An air bearing force sensing manipulator was used to assemble the Keyhole subassembly.



Final Assembly

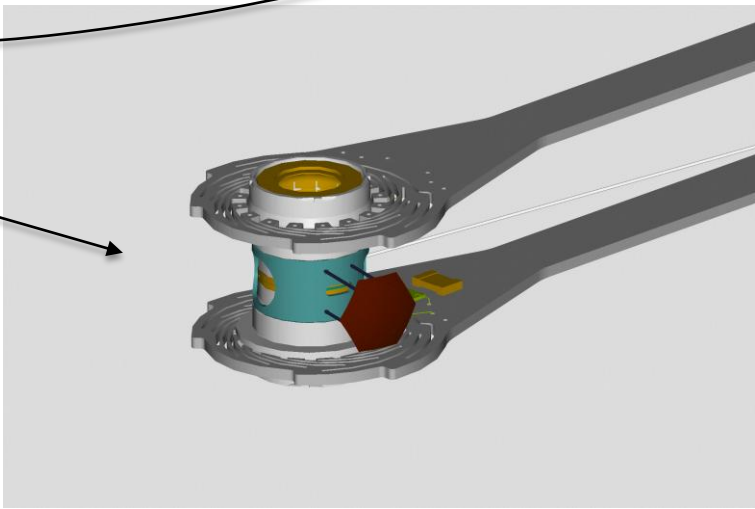
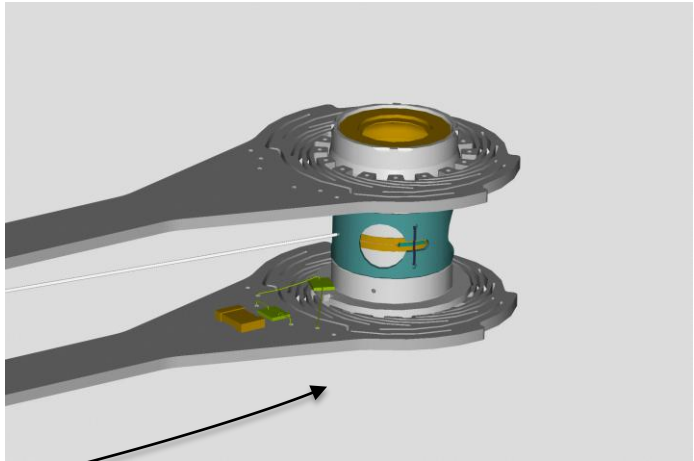
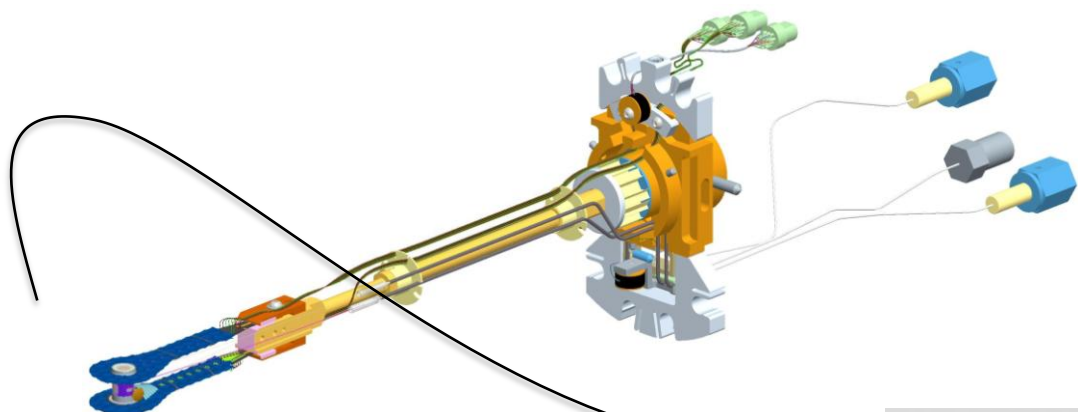
- The Keyhole target was successfully assembled using the FFAM.

Photos showing assembled target on the FFAM



Convergent Ablator Target

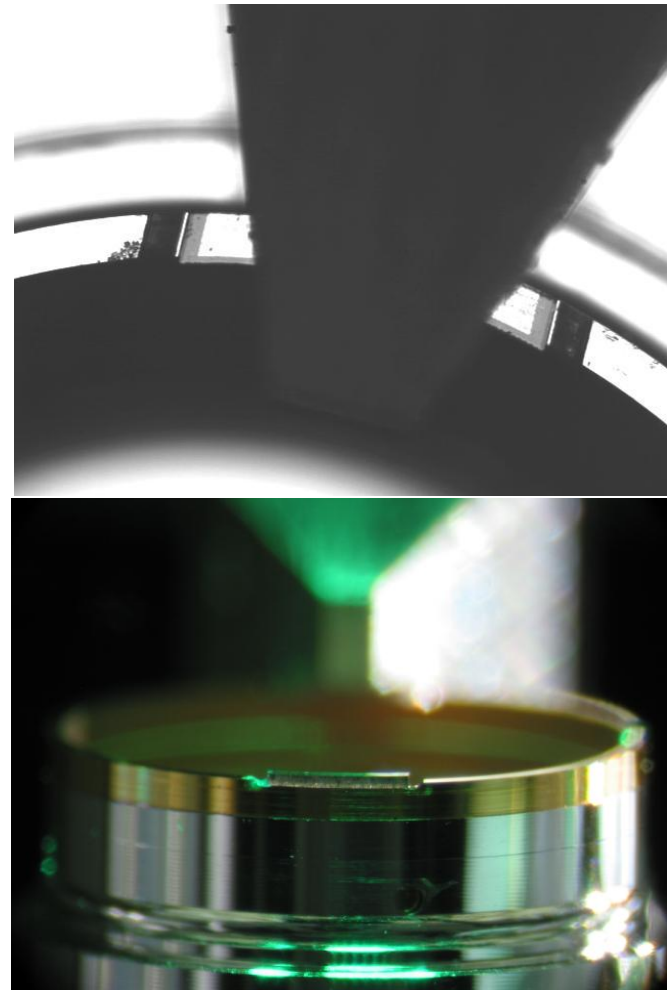
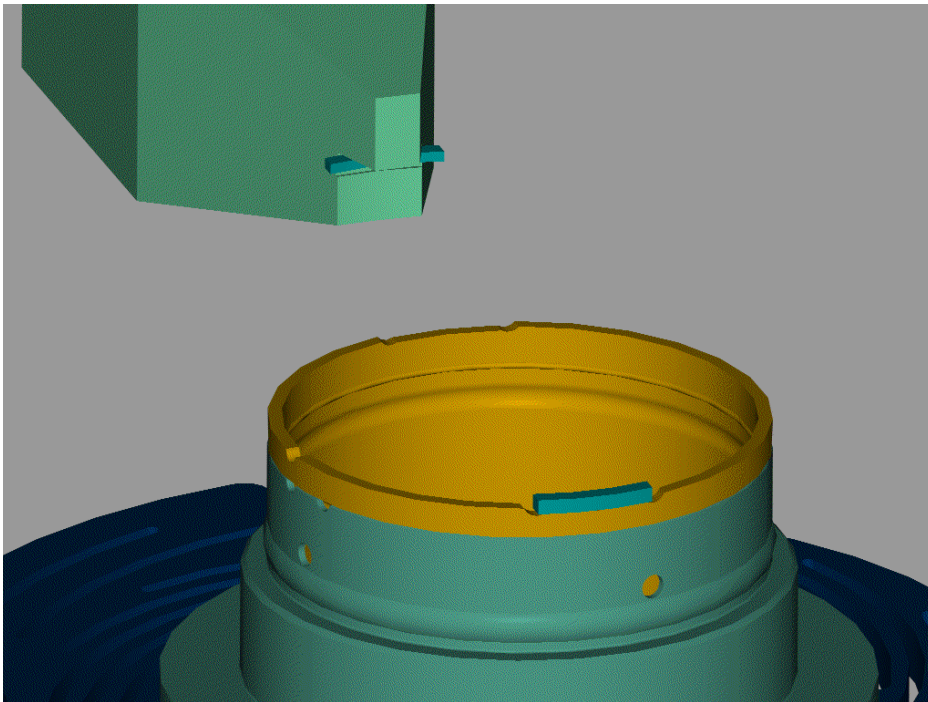
- Target description ?



Convergent Ablator Subassembly

- Diamond window were installed on the reconfigured assembly station. The OCMM was used to verify glue thickness and position of the diamond window

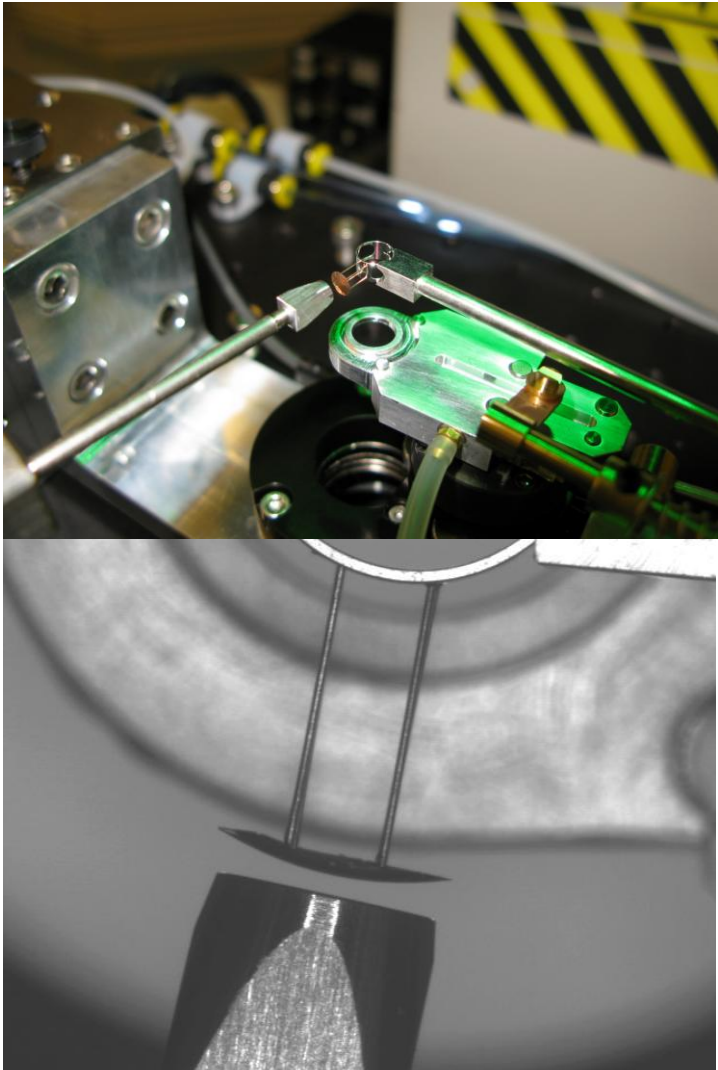
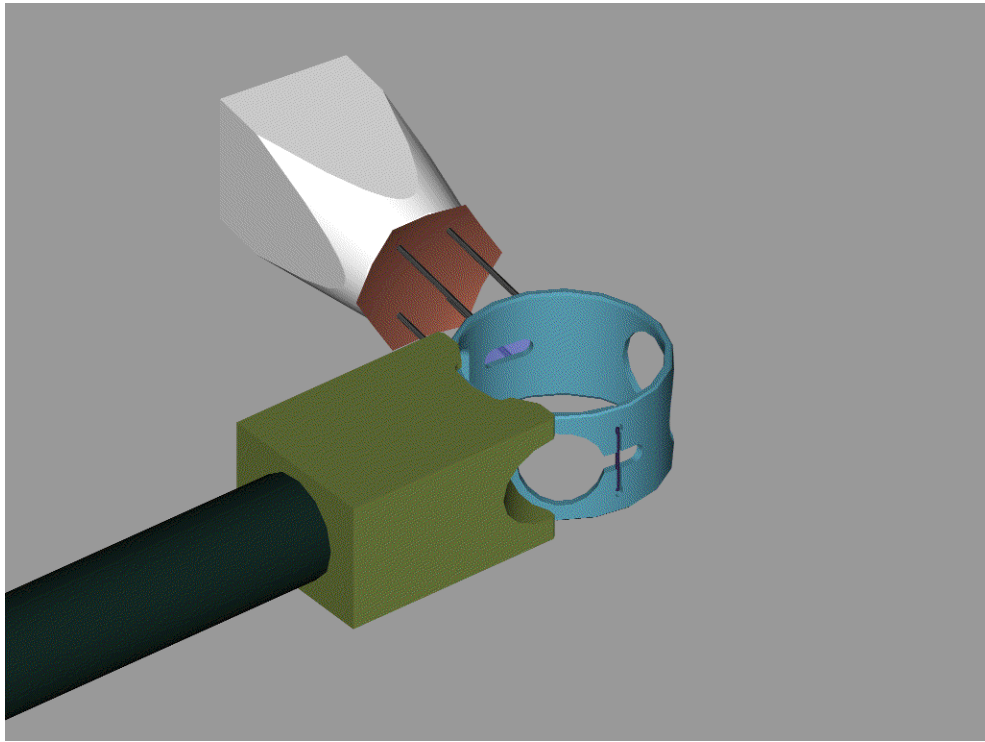
Photos and model showing the diamond window install



Convergent Ablator Subassembly

- Copper back lighter was installed on the reconfigured assembly station. The OCMM was used to verify position of the back lighter

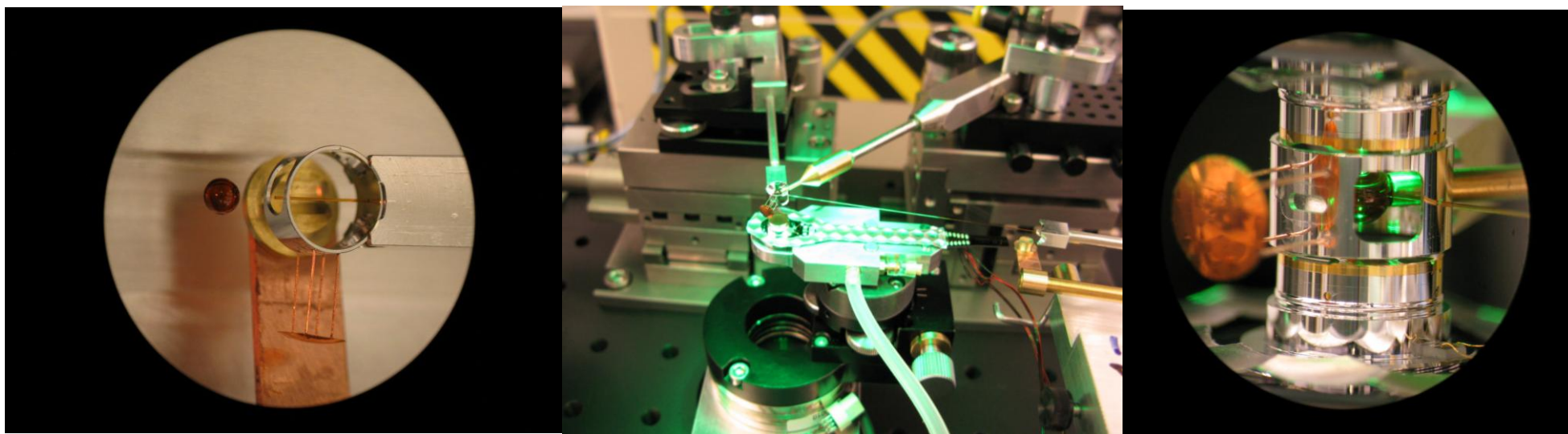
Photos and model showing the back lighter installation



Convergent Ablator Final Assembly

The capsule is threaded through the diagnostic band and delivered to the assembly station and tented.

Photos showing the capsule tenting sequence.



Convergent Ablator Final Assembly

Completed Convergent Ablator target

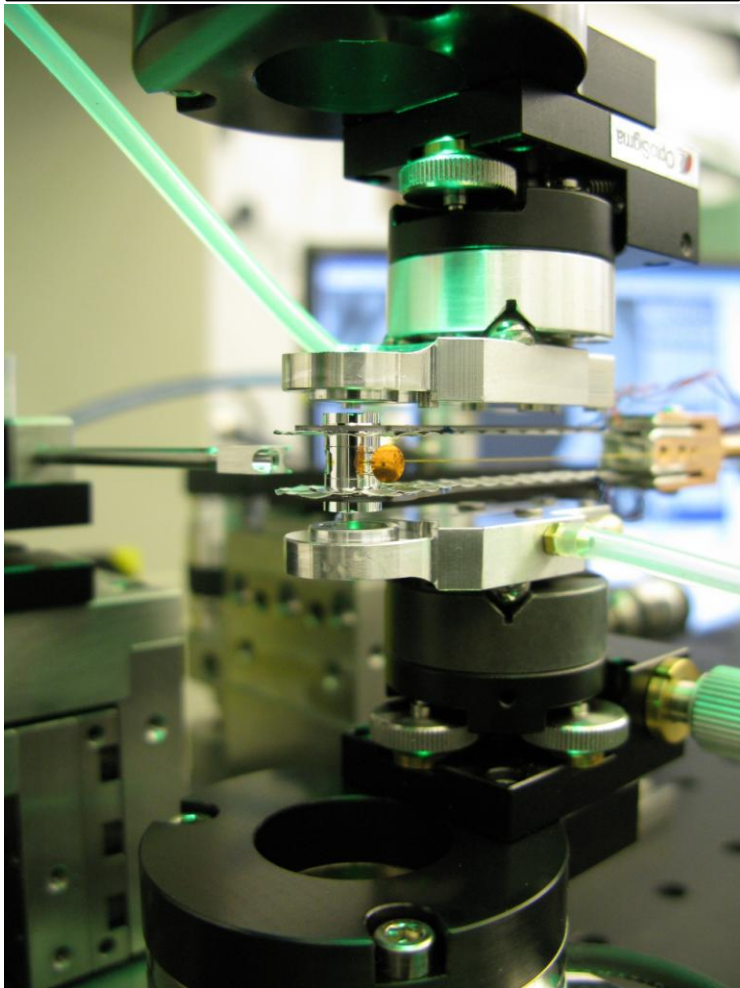
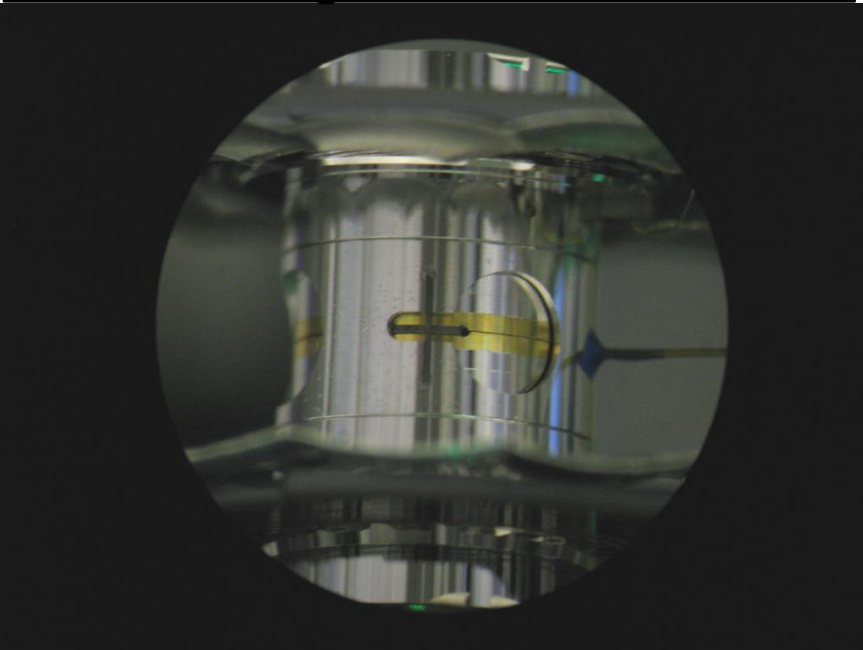


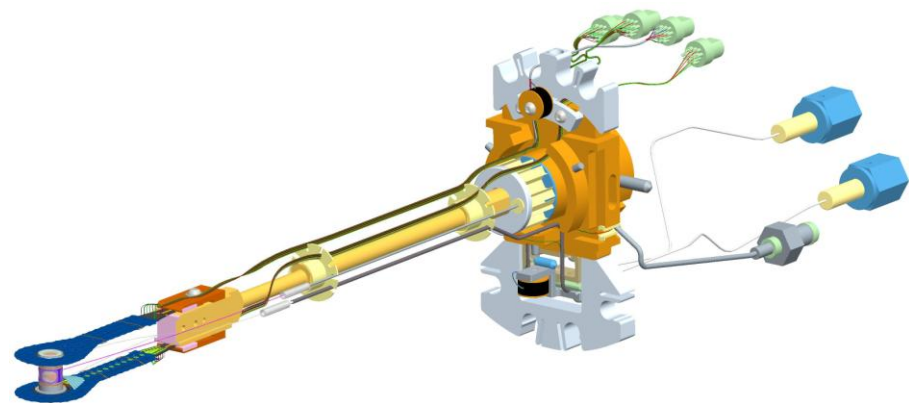
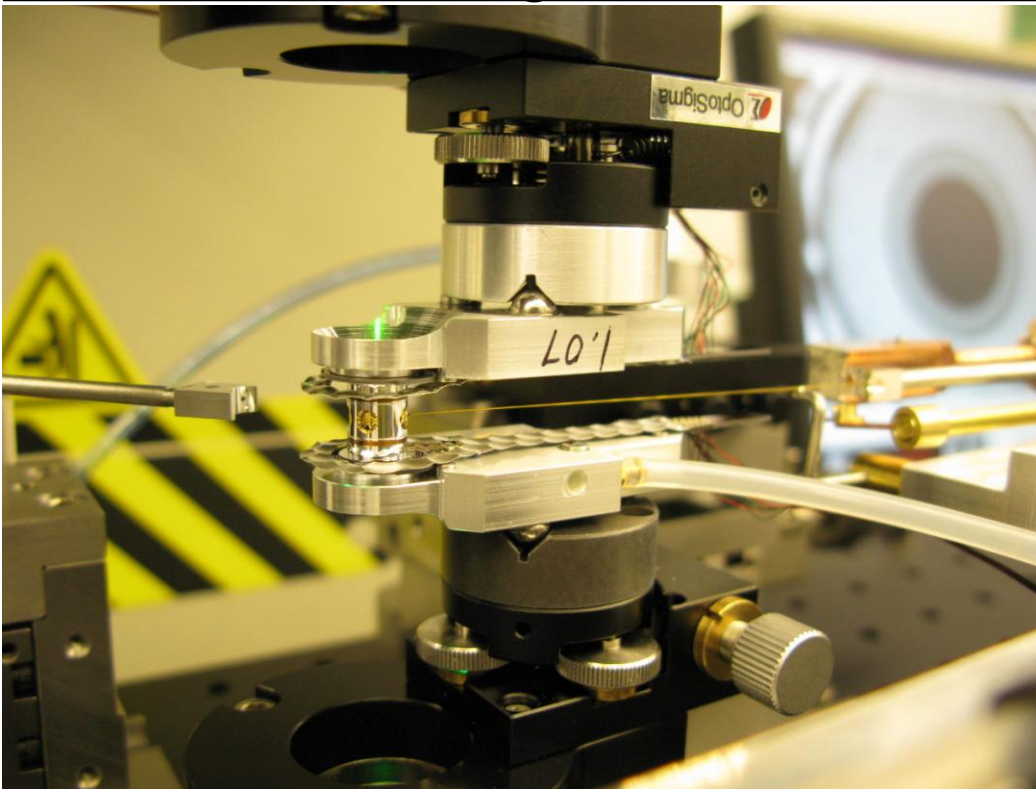
Photo of diamond window and tungsten fiducial



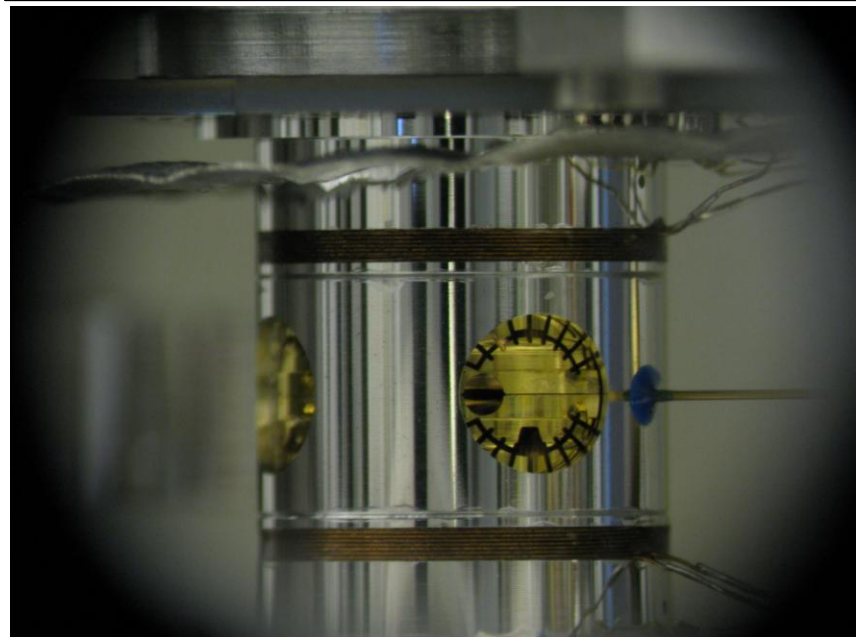
Ignition Target

- Target Description

Photo showing completed Prototype Target



Close-up photo of starburst



Conclusion

- **The Flexible Final Assembly machine is being used to assemble production ignition targets for the National Ignition Campaign**
- **The FlexFAM successfully demonstrated that it can assemble inertial confinement fusion ignition targets that meet the required micron-level tolerances.**
- **Using the FlexFAM, one person can build a target in a single 8-hour work shift.**
- **Novel target assembly tooling developed for and tested on the FlexFAM is being migrated to other machines being used to build NIC targets.**