2-2002

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Original Publication Citation

Sukenik, C.I., & Busch, H.C. (2002). A Rf discharge cell for saturated absorption spectroscopy of metastable argon. *Review of Scientific Instruments, 73*(2), 493-494. doi: 10.1063/1.1433953

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Citation: Review of Scientific Instruments **73**, 493 (2002); doi: 10.1063/1.1433953
View online: http://dx.doi.org/10.1063/1.1433953
View Table of Contents: http://scitation.aip.org/content/aip/journal/rsi/73/2?ver=pdfcov
Published by the AIP Publishing

A rf discharge cell for saturated absorption spectroscopy of metastable argon

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(Received 9 October 2001; accepted for publication 15 November 2001)

We have produced a rf discharge in ^{40}Ar and used saturated absorption spectroscopy to offset lock a Ti:Sapphire laser to the absorption peak of the $4^3P_2 \rightarrow 4^3D_3$ cooling transition at 811 nm. We describe the procedure for fabrication of the cell and production of the discharge. © *2002 American Institute of Physics.* [DOI: 10.1063/1.1433953]

Noble gases, alkali, and alkaline earth atoms are the principal species studied in experiments in laser cooling and trapping of atoms.[1] Unlike the alkalis and alkaline earths, though, noble gases must be trapped in an excited metastable state because laser sources in the vacuum ultraviolet for initiating a cooling transition from the ground state are not readily available. Excitations from metastable states, by contrast, are conveniently located in the visible to near infrared spectral region. For example, the $4^3P_2 \rightarrow 4^3D_3$ cooling transition in ^{40}Ar occurs at 811 nm. We are planning to carry out studies of ultracold molecule production in a dual species magneto-optic trap containing both rubidium and argon. As a result, we have constructed an rf discharge cell and used it to lock a Ti:Sapphire laser for trapping argon atoms. The use of both rf discharge and direct current discharge cells has been reported in the literature, but details on the construction of the cell are often omitted. Furthermore, problems with degradation of the cell over time, presumably due to contamination, have also been noted. Lu *et al.* recently described the construction of a direct current discharge for saturated absorption spectroscopy in helium.[2] In this Note, we detail how we fabricated and operate a rf discharge cell for saturated absorption spectroscopy in argon.

We chose to use a rf discharge cell as opposed to a direct current discharge cell so as to eliminate the possibility of cell contamination resulting from sputtering of the electrodes, a common problem. The cell was made entirely from Pyrex glass. It is circular in cross section with a 1 in. diameter, and is 3 in. long. Although the optical quality of the Pyrex blanks which were glass blown onto the ends of the cell is not as good as optical flats, it is easier to fabricate than fritting a flat and works fine for saturated absorption spectroscopy. A small Pyrex tube stem was blown onto the center of the cell for evacuation and loading of the argon. The other end of the stem was blown onto a commercial glass-to-metal connector terminated with a 1 1/3 in. miniconflat flange as shown in Fig. 1.

To reduce the possibility of contamination of the discharge over time, considerable care was taken to thoroughly clean the glass cell. The first step of the cleaning process involves chemical cleaning. The cell was placed in a heated ultrasonic bath with Alconox detergent for about 1 h. The cell was then thoroughly rinsed using deionized water followed by methanol. Finally, the inside of the cell was exposed to a 50% solution of hydroflouric acid for approximately 1 min followed by a second methanol rinse. At this point, the cell was ready to be placed on the vacuum manifold used for evacuation and filling. We used a small conflat vacuum system attached to a 60 l/s Varian ion pump. A lecture bottle containing research grade argon was also attached to the vacuum system at this time. The entire vacuum system was roughed out and the ion pump started. The regulator on the lecture bottle was left open to purge the incoming gas lines directly to the lecture bottle valve. Once the vacuum system had reached a pressure of about 1×10^{-7} Torr, as measured by the current on the ion pump, the cell was flamed with a Bunsen burner for about 15 min, sufficient to drive most of the remaining contaminants off the interior of the cell walls.

As a final cleaning measure, the cell was filled with several Torr of research grade argon, valved off, and a rf discharge (described next) operating at 3 W, was allowed to run for 1 h. The electron bombardment helps to remove any remaining contaminants embedded near the surface. After the

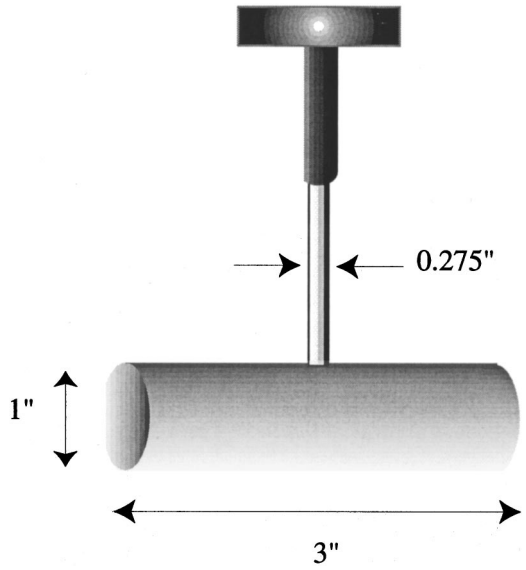

FIG. 1. Sketch of the Pyrex cell used to make a rf discharge in argon.

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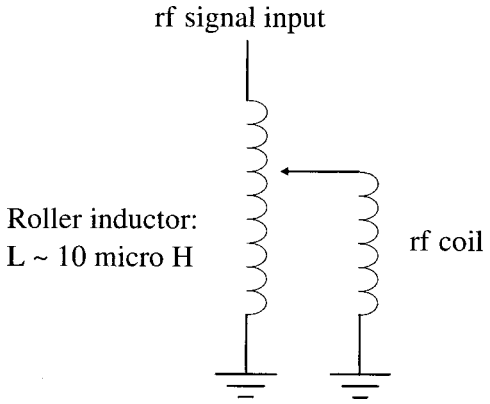

FIG. 2. Schematic of a simple circuit which uses a roller inductor to impedance match the rf source to the cell coil.

discharge cleaning procedure, the cell was once again evacuated and allowed to pump overnight. Finally, the cell was filled with approximately 50 mTorr of argon and a torch was used to pinch off the stem, leaving a sealed cell. The ultimate pressure of the cell before filling with argon was $<1 \times 10^{-7}$ Torr.

The rf discharge was produced by wrapping a coil, which serves as an antenna, around the cell. We found the dimensions of the coil are not critical. The coil, which was made using 14 gauge magnet wire, consisted of 20 turns wrapped just outside the glass cell with the wires terminated to a BNC connector. The discharge was driven by a voltage controlled oscillator (Mini-Circuits ZOS-50)/amplifier (ENI 300P) combination. The amplifier was able to deliver up to 4 W of power, but we found that the discharge can be sustained easily with as little as 400 mW. We typically drove the discharge at 25 MHz, though it worked fine over a range of frequencies. In order to ensure that the forward power is delivered to the cell and not simply reflected by the coil, impedance matching is critical. Impedance matching can be achieved with a simple roller inductor as shown in Fig. 2. We found it convenient to purchase a commercial antenna tuner (MFJ 969) which is manufactured primarily for amateur radio enthusiasts. To achieve the best possible impedance matching, a roller inductor—which allows for continuous tuning—is preferable to a step inductor which only allows for discrete tuning. The MFJ 969 also has a built-in forward and reverse power meter for monitoring the power delivered and the standing wave ratio. Using the antenna tuner, we were able to impedance match such that the reflected power was less than 5% of the incident power.

With rf sources, interference in other electronics from broadcasting can be a problem. We found that although the cell itself did not seem to cause much interference, the simple coaxial cable (RG-58) that we used to deliver the rf did create substantial interference in nearby electronics. This interference was virtually eliminated, though, by wrapping the entire length of the coax cable with a grounded cylindrical mesh.

We have fabricated a rf discharge cell for saturated absorption spectroscopy in ^{40}Ar. Fabrication of the cell requires attention to proper cleaning in order to avoid degradation of the cell over time. Proper impedance matching of the rf source to the coil is also important. A simple roller inductor does the job nicely. In order to reduce rf broadcasting throughout the lab, the coaxial cable used to deliver the rf from the source to the coil should be shielded. We have run the cell in a standard saturated absorption spectrometer[3] several days a week for three months with no indication of line broadening or quenching arising from cell contamination. These observations lead us to expect that the cell will operate for years.

The authors thank M. D. Havey for useful discussions and assistance with the glassblowing. They also thank S. Popovic, M. S. Walhout, and C. R. Orzel for useful discussions.

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