Two-photon imaging of a magneto-optical trap in a micro-fabricated cell for cold-atom sensors

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***Abstract*—We have produced a sample of laser-cooled atoms in a micro-fabricated alkali vapor cell using a grating MOT to direct the beams. We show that by detecting the blue fluorescence resulting from a two-photon cascade transition, we improve the rejection of cooling light scattered from the grating.**

I. INTRODUCTION

Laser cooling has driven technological advances in metrological experiments due to the long interrogation times and unperturbed atomic structure provided by cold-atoms [1], [2], [3]. However, the bulky apparatus of cold atom clocks and interferometers have largely confined these instruments to laboratory environments, such that the growing market for compact atomic devices is currently dominated by pre-existing, miniaturized hot-vapor-cell technologies [4], [5], [6].

Recent studies into compact cold-atom devices have focused on optical miniaturization and total power consumption [7], [8], [9]. However, the UHV system has thus far eluded miniaturization on a micro-fabricated scale.

In previous literature, aluminosilicate glass (ASG) has been demonstrated to exhibit helium permeation rates significantly lower than borosilicates. This property makes ASG an attractive candidate for the development of MEMS cells that could potentially maintain UHV below 10^{-7} Torr for timescales exceeding a few months [10], [11].

In this paper we report the fabrication of ASG based MEMS UHV cells with an optimized anodic bonding process for a high yield of successful cells. This study discusses laser cooling in such geometries and background-free imaging to overcome the dominant scatter in such planar stacked devices. This technology is proposed with an outlook to a passively-pumped UHV cell.

II. CELL FABRICATION

The vacuum cell configuration, presented in Fig. 1 (a), consists solely of a silicon frame sandwiched between two ASG wafers using anodic bonding [12], [13]. The silicon frames used in these tests are fabricated using a potassium hydroxide (KOH) wet etch through a 4 mm frame thickness. To achieve such an etch depth, 2 mm deep concentric rectangles are etched on each side of the silicon wafer surface. The KOH etching of the rectangle follows the Miller indices of the silicon crystal orientation to produce 54.7° inner walls [14]. Over-etching is then used to produce a smooth inner wall surface orthogonal to the upper and lower bonding surfaces.

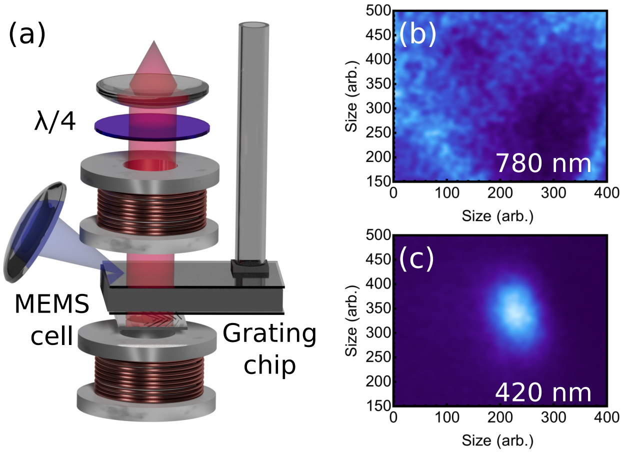

Fig. 1. (a): Micro-fabricated alkali vapor cell coupled to a grating MOT system. The science cell consists of silicon frame, anodically bonded to equally sized ASG. The upper ASG glass is drilled and bonded to a silicon washer to permit anodic bonding to a borosilicate tube that connects the cell to a standard ion pump and alkali dispenser. (b): Imaging the 780 nm fluorescence. (c): Imaging the 420 nm fluorescence with a bandpass filter.

The outer cell walls are diced to achieve frame dimensions of 40 mm× 20 mm× 4 mm. Such dimensions were chosen to provide a large surface bond area for increased probability of a hermetic seal, whilst providing a 12 mm inner diameter to facilitate laser cooling with 1 cm diameter beams. The upper ASG is drilled and bonded to a silicon washer and borosilicate tube that is sealed to a vacuum flange. This attachment permits these bonded cells to be connected to a standard ion pump to characterize the cell vacuum and perform initial laser cooling tests. A thorough study of anodically bonding ASG MEMS cells will be presented at the conference.

III. ACTIVELY PUMPED MEMS MOT

The MEMS cell was pumped down to 10^{-9} Torr and aligned with a grating-magneto-optical-trap (GMOT) [15] for a compact and robust laser cooling platform. With the silicon walls of the MEMS cell restricting optical access to non-orthogonal angles for imaging, the CCD must look down upon a scatter dominated diffractive optic. Imaging with 780 nm light restricts the ability to well resolve cold atom fluorescence from environmental scatter, as shown in Fig. 1 (b). To overcome the scatter in this planar stacked geometry, a second laser is used to couple atoms to the $5D_{5/2}$ electronic state, where atoms can cascade via the $6P_{3/2}$ state with 420 nm light emission [16], [17]. Imaging with a CCD and 420 nm bandpass filter refines the observed light to the atomic fluorescence, shown in Fig. 1 (c).

IV. CONCLUSION AND OUTLOOK

Our characterization of anodically bonding aluminosilicate glass vacuum cells for UHV applications has been optimized for a high yield of successful cells. Such MEMS cells have been connected to an external ion pump and associated to a laser cooling optics system to demonstrate the detection of a magneto-optical trap using background-free imaging. The latest results and outlooks will be presented at the conference.

ACKNOWLEDGMENT

J. P. M. gratefully acknowledges support from the English Speaking Unions Lindemann Fellowship. R. Boudot is supported by Délegation Générale de l'Armement and the NIST guest-researcher program. The authors would like to thank D. Bopp and Dr. Moshe for helpful discussions. The views, opinions, and/or findings contained in this letter are those of the authors and should not be interpreted as representing the official views or policies of the Department of Commerce or the U.S. Government.

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