Wafer-level fabrication of mm-sized all-glass atomic vapor cells

Prajal Chettri[1], Ruan Viljoen[2], Vincenzo Tamborra[2], Vito Giovanni Lucivero[1, 2, 3]

1. Dipartimento Interuniversitario di Fisica, Universita degli Studi di Bari Aldo Moro e Politecnico di Bari, 70126 Bari, Italy

2. QSENSATO Srl, Via Giovanni Amendola 173, 70126 Bari, Italy

3. ICFO - Institut de Ciències Fotòniques, The Barcelona Institute of Science and Technology, 08860, Castelldefels, Barcelona, Spain

Abstract: We present wafer-level fabrication of millimeter-scale, all-glass atomic vapor cells using femtosecond laser direct writing, enabling scalable production for quantum sensing and metrology applications.

Alkali-metal-vapor cells are a key component of many quantum technologies, providing a sensitive atomic medium for precision measurements of electromagnetic fields [1], as well as for tests of fundamental physics. The increasing demand for compact and deployable quantum sensors has motivated strong efforts toward vapor-cell miniaturization, while maintaining long atomic coherence and high optical quality. Wafer-level fabrication approaches offer a practical path forward by enabling scalability, robustness and integration with optical components in chip-scale atomic devices [2, 3].

Femtosecond laser irradiation followed by chemical etching (FLICE) has been recently demonstrated as a novel method to fabricate three-dimensional hollow microstructures in transparent materials [4]. This approach enables the realization of all-glass laser-written vapor cells (LWVCs) potentially suitable for a variety of quantum sensors such as optically pumped magnetometers (OPMs), RF sensors, atomic clocks, and gyroscopes.

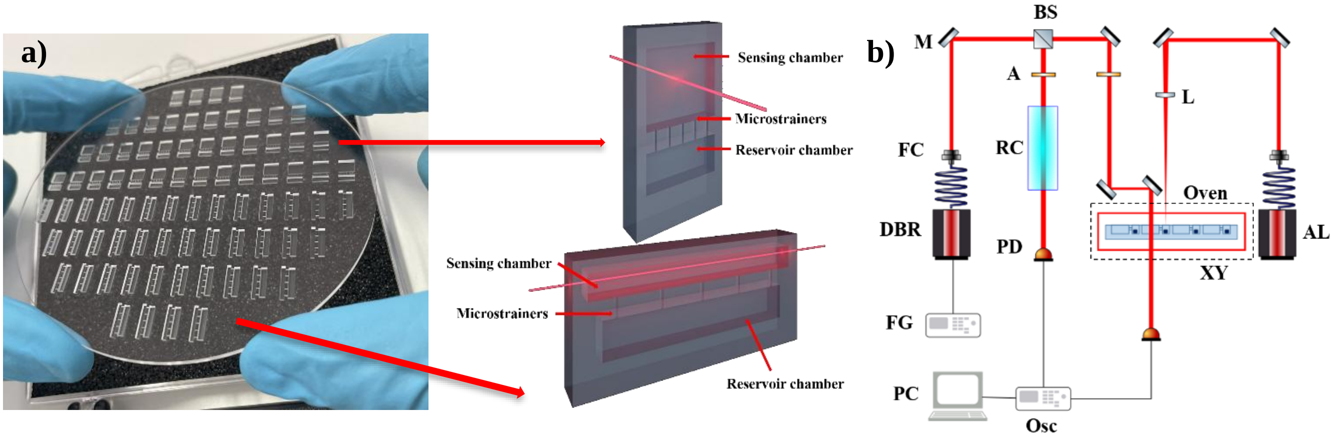

Fig. 1: (a) FLICE-fabricated all-glass wafer showing two atomic vapor cell geometries (transverse and longitudinal). (b) Experimental schematic for simultaneous high-power laser activation and absorption spectroscopy characterization. DBR—distributed Bragg reflector laser; AL—activation laser; FC—fiber collimator; RC—reference Cs vapour cell; M—mirror; BS—beam splitter; A—attenuator; L—lens; PD—photodetector; FG—function generator; Osc—oscilloscope; XY—translation stage

In this work, we present wafer-level fabrication of millimetre-scale alkali vapor cells using the FLICE technique. The flexibility of the approach allows for multiple geometries to be fabricated on a single wafer, as illustrated in Fig 1.a. Atom-dispenser pills enable wafer-scale activation of these LWVCs (Fig 1.b), offering favorable prospects for scalable manufacturing. Furthermore, we describe our ongoing efforts in wafer-scale glass-to-glass bonding under both vacuum and high-pressure conditions, aiming to establish a single, highly flexible facility capable of producing vapor cells for a wide range of applications.

References

[1] J. Kitching, J. P. Shaffer, and D. Budker, 'Atom-based quantum sensing of electromagnetic fields', *Optica*, vol. 12, no. 12, p. 2008, Dec. 2025

[2] J. Kitching, 'Chip-scale atomic devices', *Appl. Phys. Rev.*, vol. 5, no. 3, p. 031302, Sep. 2018

[3] D. G. Bopp, V. M. Maurice, and J. E. Kitching, 'Wafer-level fabrication of alkali vapor cells using in-situ atomic deposition', *Journal of Physics: Photonics*, vol. 3, no. 1, p. 015002, Jan. 2021

[4] V. G. Lucivero, A. Zanoni, G. Corrielli, R. Osellame, and M. W. Mitchell, 'Laser-written vapor cells for chip-scale atomic sensing and spectroscopy', *Opt. Express*, vol. 30, no. 15, p. 27149, Jul. 2022