Sub-Doppler linear spectroscopy in a vapour confined in an opal

E. Moufarej[1], P. Ballin[1], I. Maurin[1], A. Laliotis[1], and D. Bloch[1]

[1]*Laboratoire de Physique des Lasers, CNRS, UMR7538, Université Paris 13, Sorbonne-Paris-Cité, 99 avenue Jean-Baptiste Clément, 93 430 Villetaneuse, France*

Presenting Author: athanasios.laliotis@univ-paris13.fr

There is a growing technological need to fabricate compact optical clocks [1]. Inspired by this need and the elimination of the Doppler broadening allowed by a sub-wavelength confinement of the atomic motion in the r.f. domain [2], we have analyzed, with high resolution laser spectroscopy, the optical spectrum of a gas confined in the sub-micron interstitial regions of an opal .

An opal consists of a crystalline arrangement of glass nanospheres, usually considered as a "soft preparation" for a photonic crystal. To avoid destructive chemical interactions between the bulk opal and the (heated) alkali-metal vapour; we have turned to a Langmuir-Blodgett (LB) preparation of a few layers opal [3,4] deposited on a window, around which the vapour cell is constructed (Fig. 1). In spite of the increasing structural defects in the successive layers of a LB opal defects, the essence of a deposited opal is a combination of a periodical layered structure -compact arrangement- with an empty gap between the flat window and the first layer of opals, promptly touching the window. With such a cell technology, the presence of a specular reflection beam is partly unexpected because the opal/window and opal/vacuum interfaces are strongly non planar (at a microscopic/wavelength scale). We show that this gap is responsible of this specular reflection and have a strong influence on it. The size of the "gap" region, relatively to the wavelength, is an essential parameter.

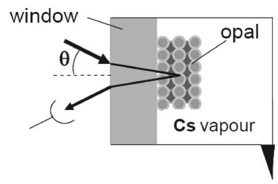

Figure 1: *Schematic of the reflection spectroscopy on an opal (magnified in the caption) infiltrated by a cesium vapour.*

On opals with 10 or 20 layers of 1 μm spheres, sub-Doppler spectra are observed under near normal incidence evoking thin cell spectroscopy, with vapour confined in the gap region. The spectra are getting broader with the incidence angle. The original finding is that for large incidence angles (θ = 40-50 degrees), there is a narrow sub-Doppler structure superimposed to a broad spectrum [3,4]. The shape of this narrow structure, observed in purely linear spectroscopy, quickly evolves with the incidence angle. Its contrast is the highest for an incident beam TM-polarised. Recent experiments have confirmed these findings with 400 nm and 750 nm spheres, or for λ = 455 nm Cs line. Our results are in agreement with a calculation taking into account the phase matching between the atomic contributions located in various layers of interstices, and the geometry of the periodical distribution of opals. From this, we deduce that the narrow structures observed for a large range of oblique incidences are associated to a genuine 3-D confinement. Our results allow envisioning very compact sub-Doppler references, applicable to weak (hardly saturable) molecular lines with a probed volume conceptually as small as several spheres. The detection of scattered light may also provide lineshapes more uniform with the incidence.

References

[1] S. Knappe et al., App. Phys. Lett., 85, 1460-1462 (2004)
[2] R. H. Dicke, Phys. Rev., 89, 472-473 (1953)
[3] P. Ballin et al., App. Phys. Lett., 102, 231115 - 231115-5 (2013)
[4] P. Ballin et al., Proc. of SPIE., 8770, 87700J-1 - 87700J-6 (2013)