European Frequency and Time Forum (EFTF) 2009, Besançon (France), April 20 – 24, 2009

CPT spectroscopy on low-temperature sealed MEMS rubidium vapour cells

C. Schori[1], Y. Petremand[2], F. Seigneur[3], T. Maeder[3], H. R. Shea[4], N. De Rooij[2], G. Mileti[1], P. Thomann[1]

[1]LTF, University of Neuchatel, Switzerland

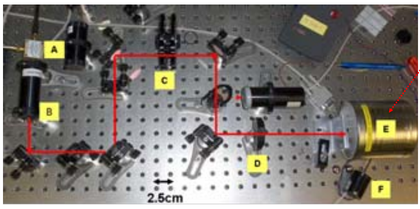
[2]SAMLAB, [3]LPM, [4]LMT, Ecole Polytechnique Fédérale de Lausanne, Switzerland

Experimental setup

Block diagram:

We perform σ+σ+ CPT spectroscopy on the rubidium D1 line (795nm) using a current modulated VCSEL (3GHz). The experimental setup is based on simple optical components which can easily be reduced in size to fit a compact physics package. Key components include:

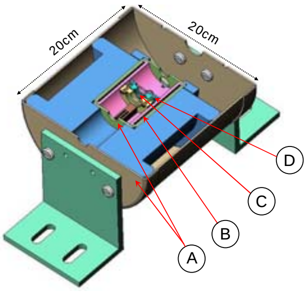
A) Bias-T for RF-modulation of laser current
B) VCSEL (Ulm-photonics) 29°C and 1.3mA.
C) ND-filter for variable attenuation
D) Quarter wave plate
E) Atomic resonator
F) Pre-amplifier



Parameters of the Atomic Resonator:

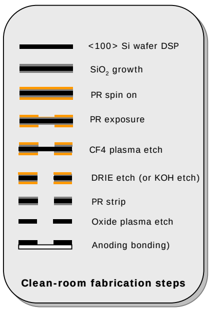
The micro-fabricated cell is placed inside a cylindrical double layer mu-metal shield. The outer shield has a length and diameter of 20 cm. The cell is heated with a twisted wire to temperatures in the range 80-95°C. Furthermore a magnetic field of 3uT is applied to isolate the clock transition between the $m_F=0$ Zeeman levels.

A) Double layer cylindrical mu-metal shield
B) Solenoid C-field (2uT/mA)
C) Position of micro-fabricated cell
D) Twisted wire to heat micro-cell (80-95°C)

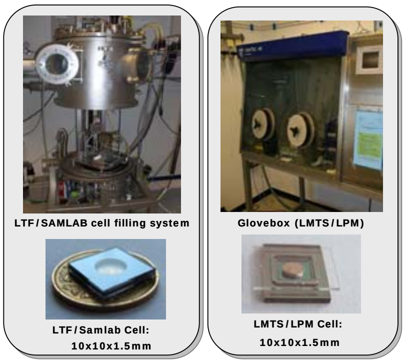


MEMS Cell fabrication and sealing at low temperature

1) Preform fabrication



2) Rb and buffer gas filling



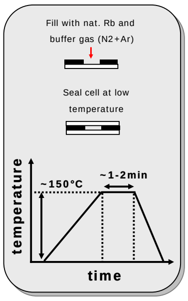
LTF/SAMLAB cell filling system

Glovebox (LMTS/LPM)

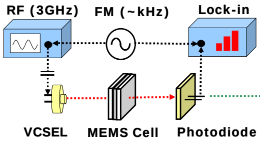
LTF/Samlab Cell: 10x10x1.5mm

LMTS/LPM Cell: 10x10x1.5mm

3) low temperature sealing

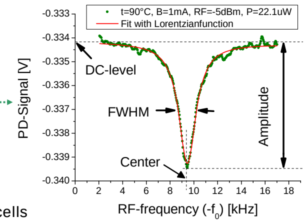


CPT spectroscopy



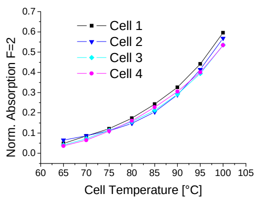
CPT Parameters:

We characterize the rubidium MEMS cells with linear absorption- and coherent population trapping (CPT) spectroscopy. The CPT resonance is measured on the 85Rb clock transition (f_0=3.035732440 Hz). The resonance is probed with the carrier and 1.order (blue) sideband of a current modulated VCSEL. The VCSEL is tuned to the D1-line (795nm)



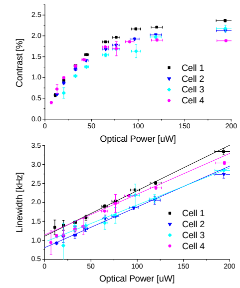
- Contrast = Amplitude/DC = 1.51%
- Linewidth = 1.75kHz (FWHM)
- Center = 9.2 kHz (relative to f_0)

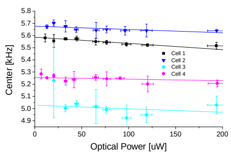
Experimental Results



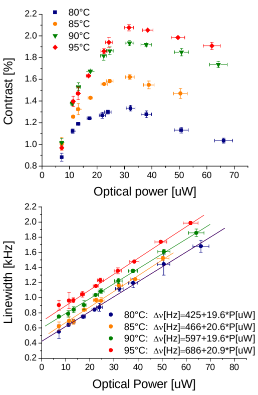
LTF/SAMLAB cells (2mm):

We compare four "identical" prepared cells (thickness 2mm, natural Rb, 30mbar N_2). **Left**: normalized linear absorption on the 85Rb F=2 transition. **Right**: CPT contrast, linewidth, and center frequency as a function of optical power. The **Table** shows measured pressure- and fractional light shift. The typical scatter in data from cell to cell is <10%.



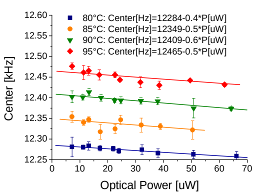


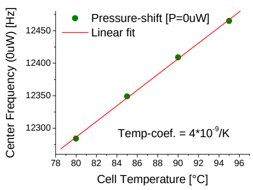
Cell #	Pressure -shift	N2 pressure	Frac. Ligth-shift
1	5587 Hz	30.8 mbar	8.9·10-11/uW
2	5676 Hz	31.3 mbar	6.1·10-11/uW
3	5026 Hz	27.7 mbar	8.9·10-11/uW
4	5255 Hz	29.0 mbar	4.3·10-11/uW



LTF/SAMLAB cell (4mm):

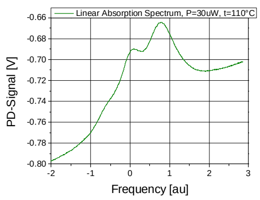
Left: CPT contrast and linewidth obtained with a 4mm cell filled with (nominal) 70mbar N_2. **Right**: CPT Center frequency as a function of optical power for different temperatures. From this data we obtain the cell temperature coefficient 4·10⁻⁹/K. This value is compatible with the measured pressure-shift ~68mbar N_2.

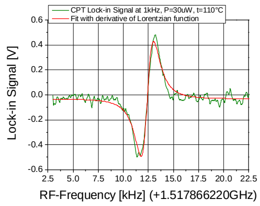




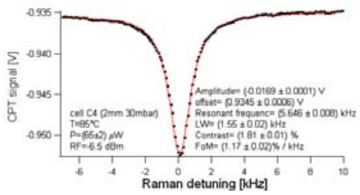
LMTS/LPM cell (0.5mm):

Right: Linear absorption and CPT signal obtained with a 0.5mm cell with (nominal) 50mbar N_2. The low contrast is probably due to a reduction in Rb vapour pressure due a layer of amorpheous silicion inside the cell.



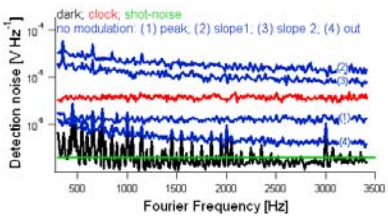


Clock Application



Signal-to-Noise:

We have measured the signal-to-noise of the LTF/Samlab cell #2 (2mm thick, 30 mbar N_2). **Top:** CPT signal with contrast of 1.81% and linewidth 1.55kHz. The corresponding Q-facor is 2·10⁶. **Buttom:** Noise Power spectral density measured with an FFT spectrum analyzer. The noise on the clock signal (red curve) is ~3uV/√Hz at 500Hz. **Table**: short-term clock stability based on the measured signal-to-noise ratio.



Parameter	Symbol	Value	Unit
Clock-frequency	f_0	3.035	GHz
Linewidth	Δf_0	1550	Hz
Quality factor	$Q=f_0/\Delta f_0$	2.0*10⁶	-
Contrast (norm. signal)	C	0.018	-
Normalized noise	-	3.2*10⁻⁶	-
Signal-to-Noise-ratio	S/N	5.6*10³	-
Allan deviation at 1sec	**$\sigma_y(\tau=1sec)$**	**2*10⁻¹¹**	-

$$\sigma_y = \frac{0.2}{Q \cdot (S/N)}$$

Conclusions

We have developed a low temperature (~150°C) and short process time (~minutes) sealing technique for MEMS rubidium vapour cells. Here we present the first spectroscopic results obtained with this new type of cells. Cells fabricated at LTF/SAMLAB show good reproducibility between different samples. For 2mm thick cells with (nominal) 30mbar nitrogen buffer gas we measure a CPT contrast and linewidth of 1.8% and 1.55kHz, respectively. Noise-measurements with this cell predict a short-term Allan deviation of 2·10⁻¹¹ using the present laboratory setup. We have also observed a CPT signal from cells fabricated by LMTS/LPM. However, for these cells we measure a low contrast which may be due to a layer of amorphous silicon reducing the rubidium density inside the cell. In the future we will record the long term stability of low temperature bonded cells with particular attention to applications in vapour cell microwave frequency standards.

Acknowledgements

We acknowledge support from the European Space Agency ESA (ESTEC contract number 20794/07/NL/GLC), the Conference Universitaire Suisse CUS (project CIMENT), the Swiss Space Office SSO, and SpectraTime SA (Neuchâtel, Switzerland).