REMOTE ALL-OPTICAL CHIP-SCALE MAGNETOMETERY

THE HEBREW UNIVERSITY OF JERUSALEM

QUANTUM SENSORS LAB
LIGHT | TIME - FREQUENCY | ATOMS

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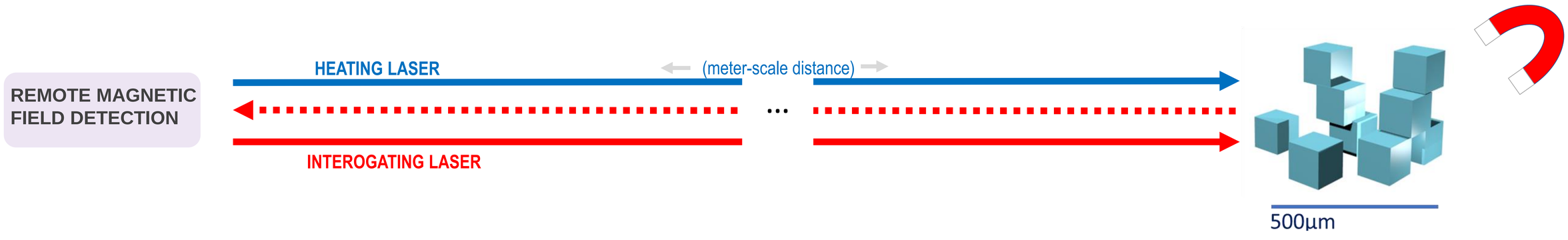
Atomic magnetometry allows the interaction between resonant light and atomic vapor, to enabling highly sensitive measurements of magnetic fields. Recently, micromachined-based mm-scale vapor-cells have enabled incredible sensitives at the fT/√Hz level, allowing the significant reduction of size, weight and power (SWaP) of such magnetometers

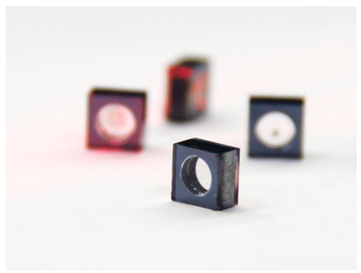
Here, we propose and demonstrate chip-scale all-optical remote magnetic sensing. Our scheme offers remote magnetic field detection with high-sensitivity & spatial resolution which may be advantageous in several applications, such as space exploration, ordnance detection, and geophysical survey [4].



MICRO-MACHINED RUBIDIUM VAPOR CELL

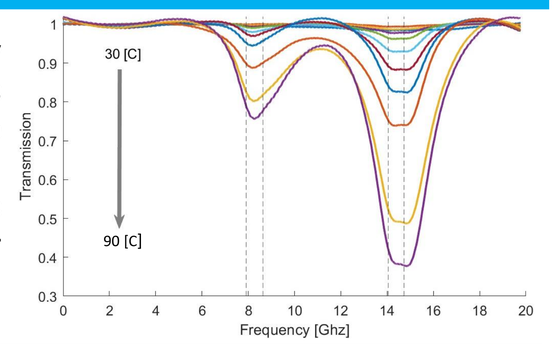
Micromachined cells may be fabricated using state of the art anodic-bonders, to allow mm-scale cells.

Our Pyrex-Si-Pyrex, cells are anodically bonded and filled with ^{87}Rb mixed with buffer gas.



REMOTE ALL-OPTICAL SPECTROSCOPY

- A heating laser is absorbed by the Si portion of the cell sides and controls remotely the density of atoms.
- ^{87}Rb D1 transmission as function of frequency for different heating power



OPTICAL MAGNETOMETRY

ZEEMAN SPLITTING

$m_{F'} = -1$ $m_{F'} = 0$ $m_{F'} = 1$

F' = 1

$\delta E = \hbar\gamma|B|$

F = 1

$m_F = -1$ $m_F = 0$ $m_F = 1$

OPTICAL PUMPING

$m_{F'} = -1$ $m_{F'} = 0$ $m_{F'} = 1$

F' = 1

σ^+

F = 1

$m_F = -1$ $m_F = 0$ $m_F = 1$

LIGHT MODULATION

$m_{F'} = -1$ $m_{F'} = 0$ $m_{F'} = 1$

F' = 1

σ^+

F = 1

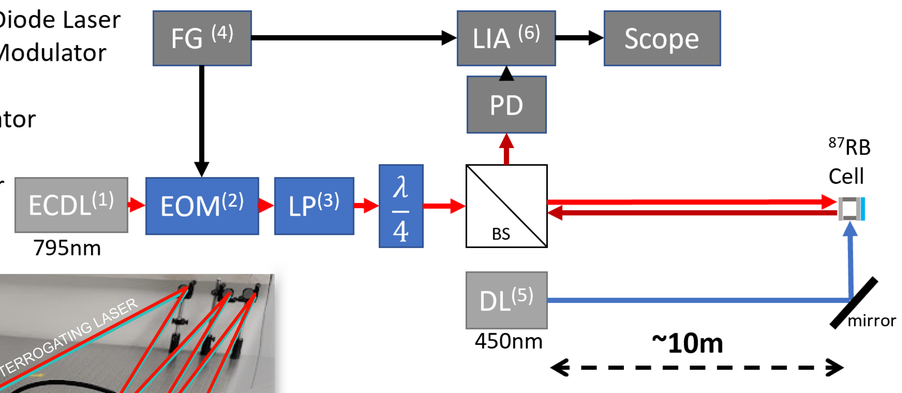
$w_m = w_l = \gamma|B|$

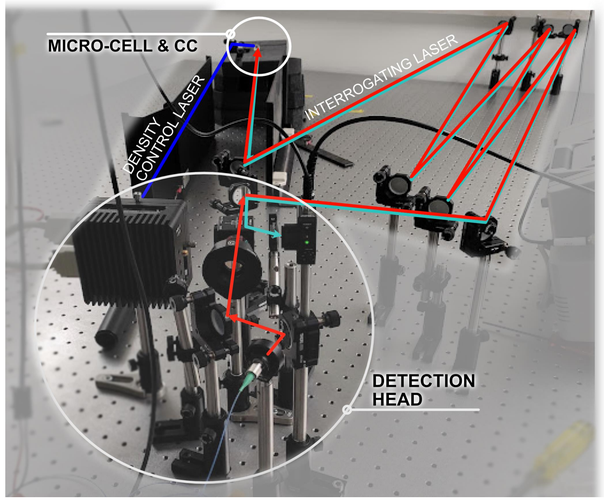
$m_F = -1$ $m_F = 0$ $m_F = 1$

REMOTE BELL BLOOM

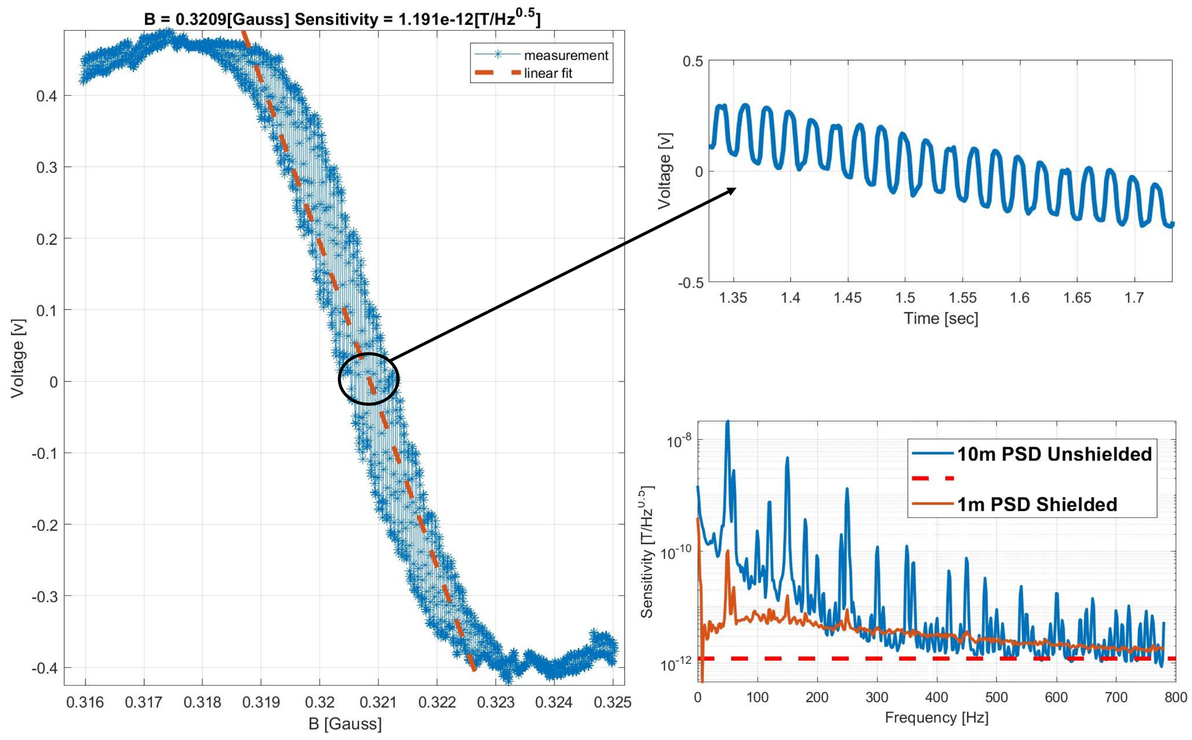
A circular polarized light modulated at the Larmor frequency optically pumps the atoms, and incudes coherent precession. By scanning the modulation frequency, we measure the magnetic resonance frequency, proportional to the external magnetic field.

(1) External Cavity Diode Laser
(2) Electro Optical Modulator
(3) Linear Polarizer
(4) Function Generator
(5) Diode Laser
(6) Lock In Amplifier





- **Sensitivity of ~1 pT/ $\sqrt{Hz}$**
- **Operates in an ambiguous unshielded environment**



SUMMARY

We remotely interrogated an optical chip-scale Bell Bloom magnetometer with a noise floor of ~1 pT/√Hz. Our system currently operates at total distance of ~ 10 m, and with mm-scale micro-cells.

Optimization of the cells geometry, buffer-gas content are expected to allow us to significantly improve these results. Yet, already in its current manifestation our system supports unprecedented sensitivities, and spatial resolution paving the path to a myriad of novel applications.

FUTURE DEVELOPMENT

- Integrated “smart-cells”: with corner cube and absorptive glass.
- “Quantum-dust”: mass fabricate thousands of sub-mm cells.
- Understand scaling laws of sub-mm scales cells for Magnetometry and Rydberg sensing.
- Replace corner cube with flat-optics (meta surface and/or micro corner cube array).

[1] Budker, D., Romalis, M.. Nature Phys 3, 227–234 (2007) [2] Kominis, I., Kornack, T., Allred, J. et al.. Nature 422, 596–599 (2003).
[3] O. Alem, …, John Kitching, and Svenja Knappe, Opt. Express 25, 7849-7858 (2017). [4] Pedreros Bustos, Felipe et al. “*Nature Communications* 9 (2018): n. pag.