Compact atomic clock with hot Rb atoms and vertical cavity surface emitting laser

Eugeniy Mikhailov,
Nathan Belcher, and Irina Novikova

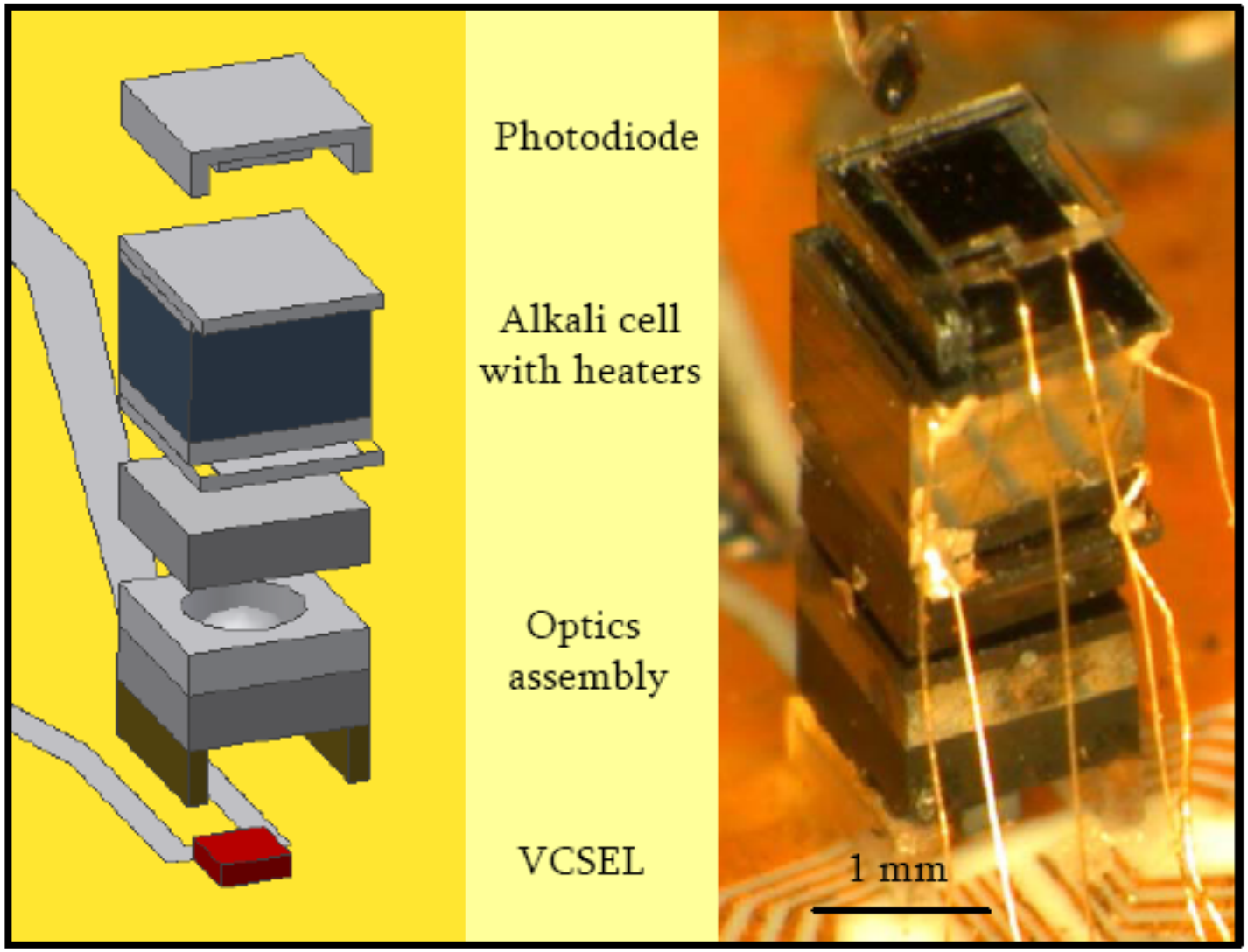
The College of William & Mary

May 23, 2009
40th Annual Meeting of the APS Division of Atomic, Molecular and Optical Physics

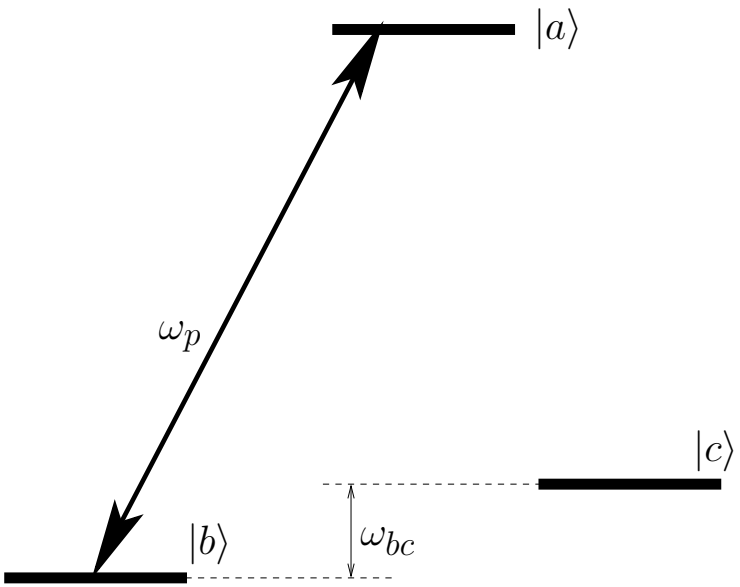
Miniature atomic clock

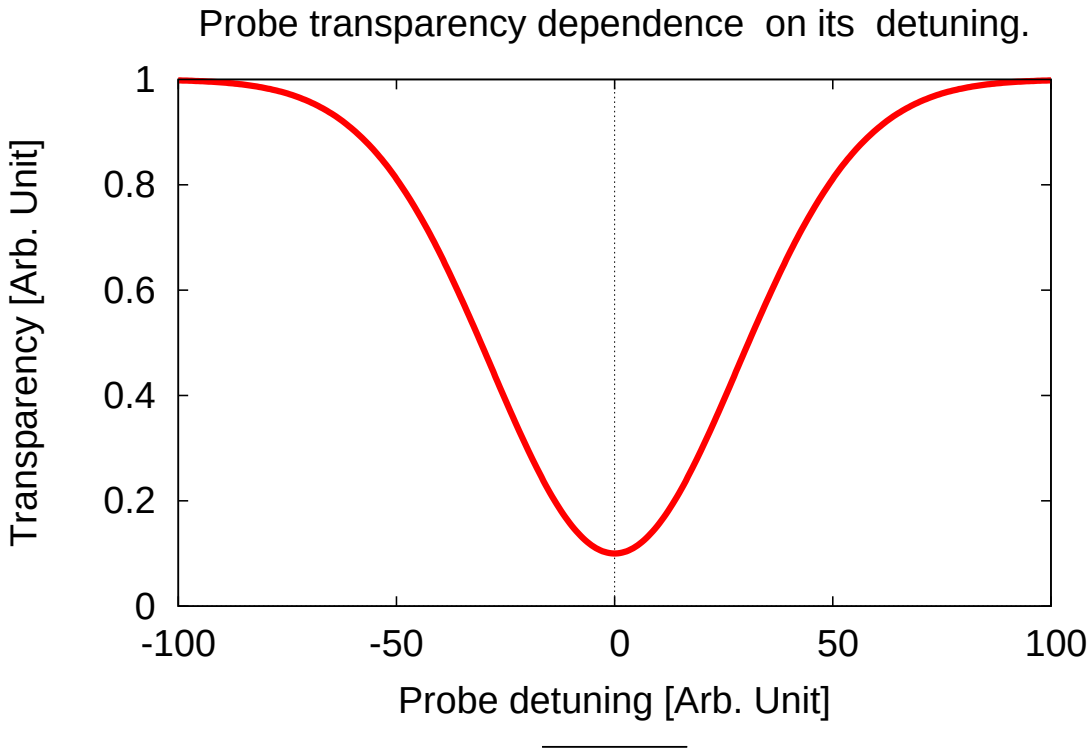
Ongoing research for compact clock
with 1cm^3 volume, and Allan deviation $10^{-12} \ldots 10^{-11}$

NIST prototype

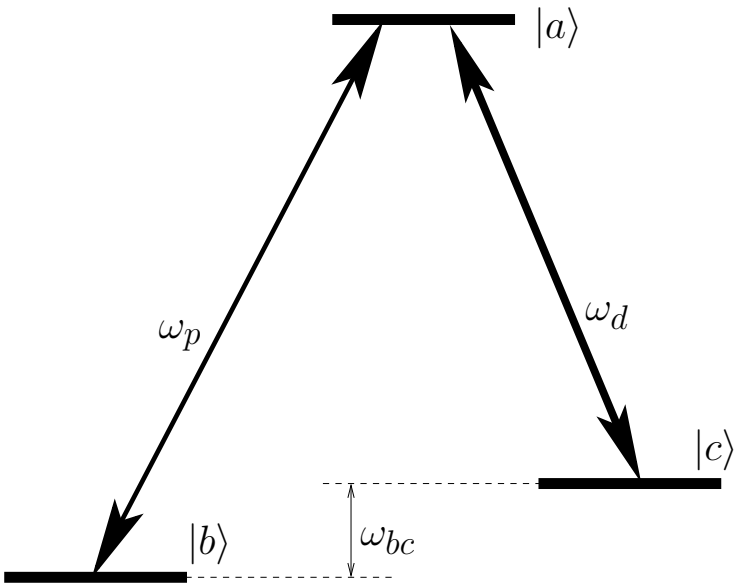


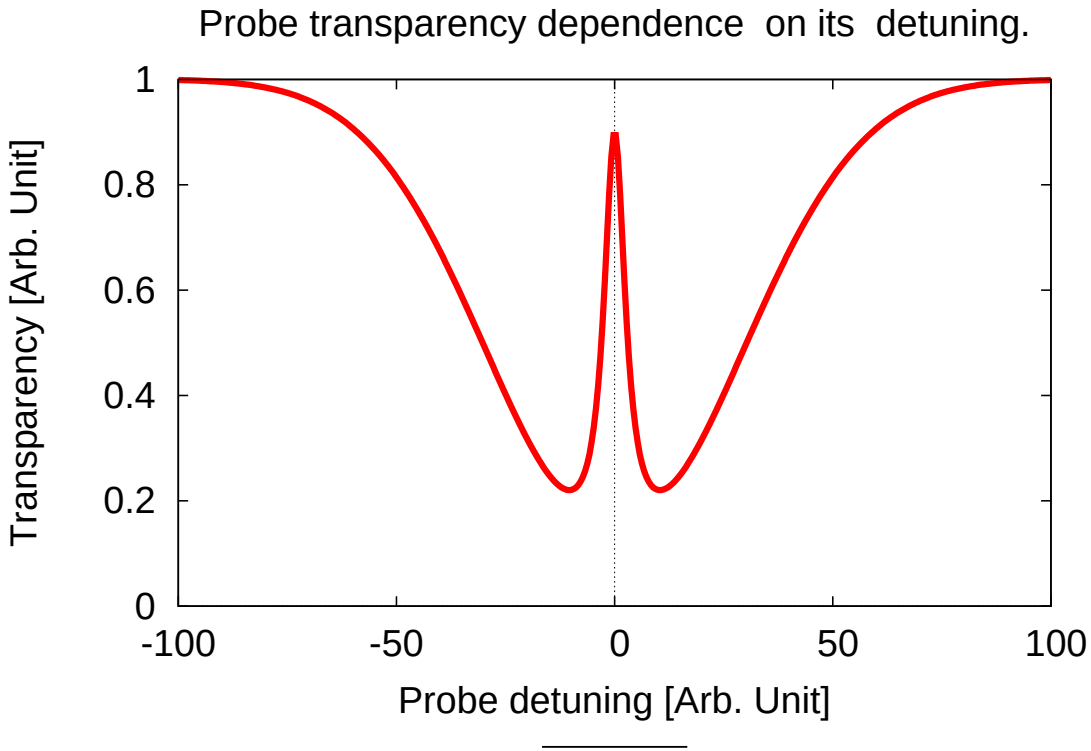
Coherent Population Trapping (CPT)



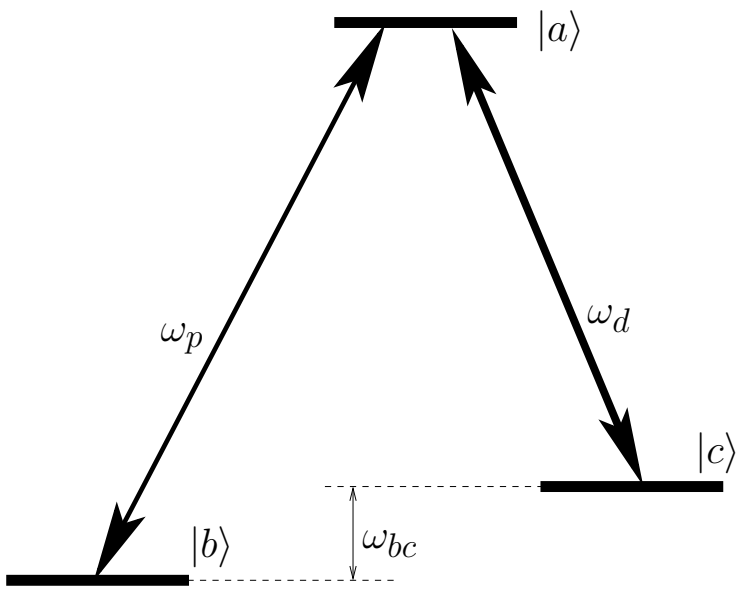


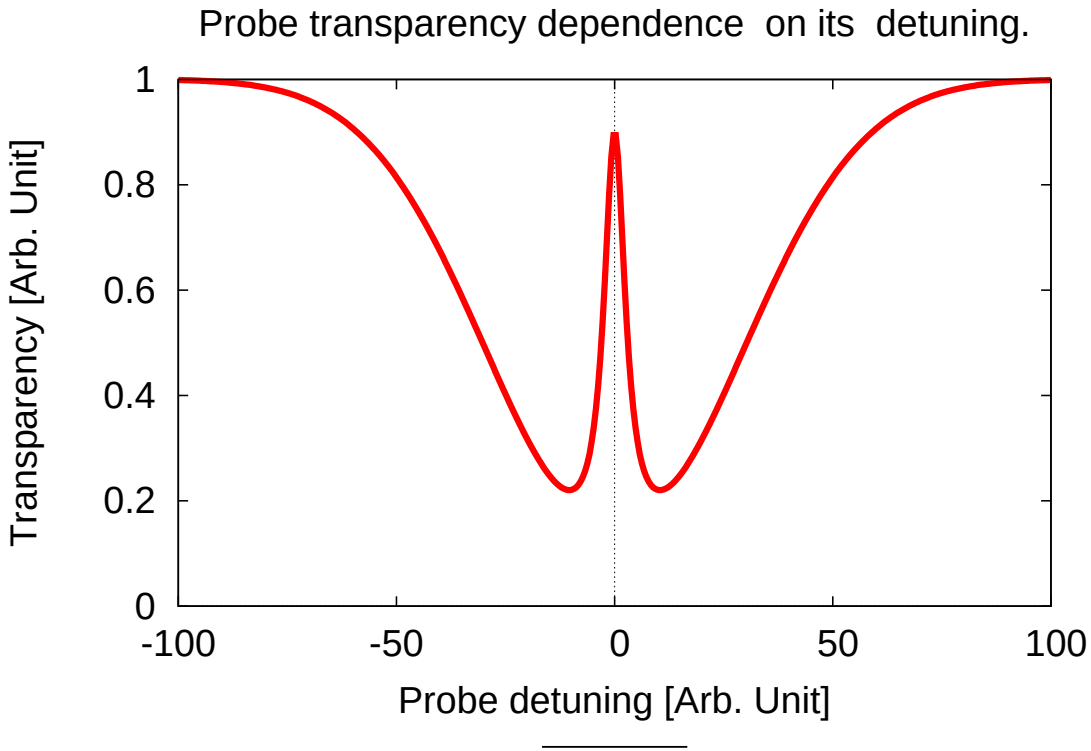
Coherent Population Trapping (CPT)





Coherent Population Trapping (CPT)

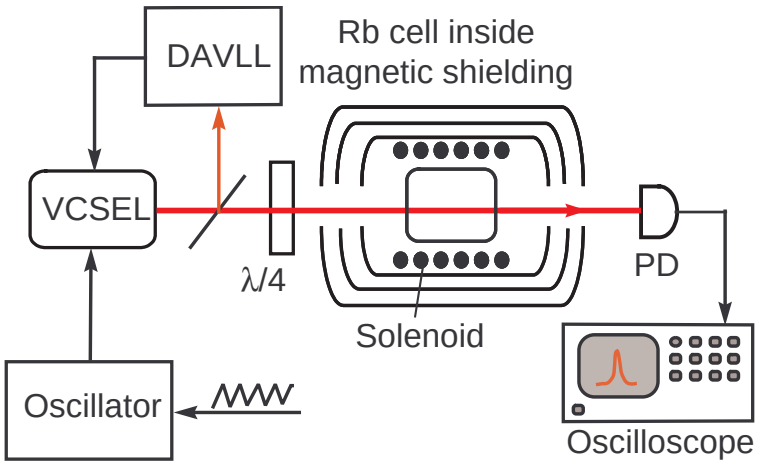


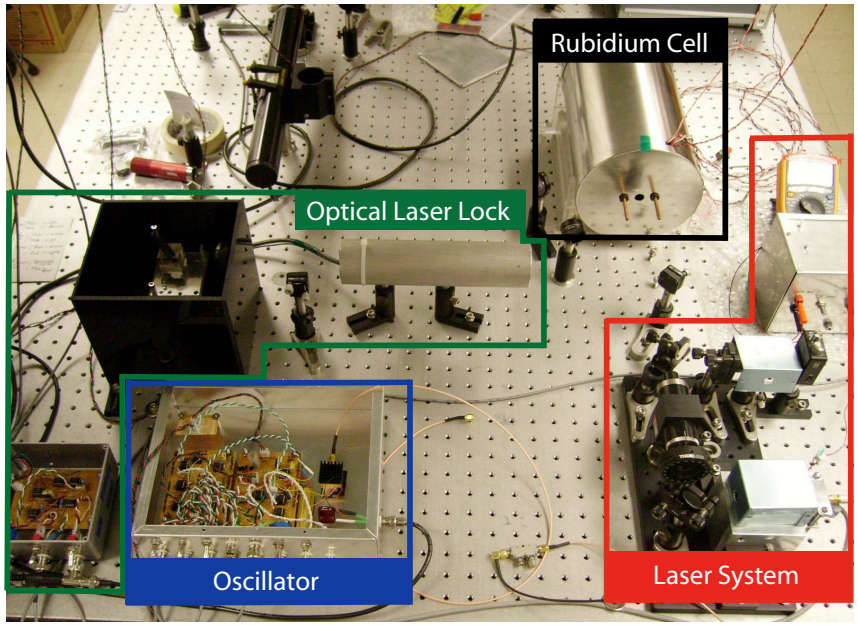


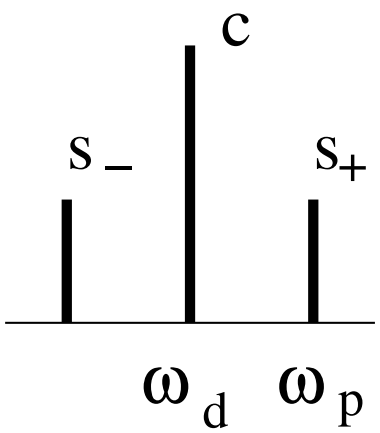
Coherent Population Trapping

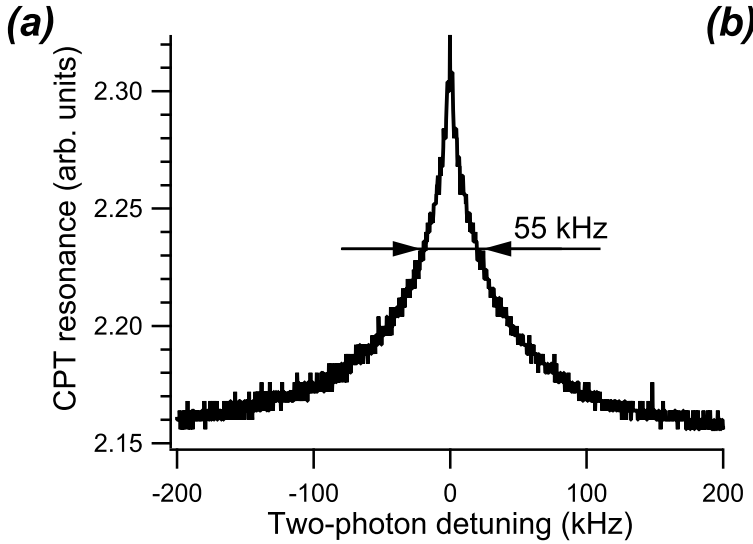
- Dark $|D\rangle = \Omega_d|b\rangle - \Omega_p|c\rangle$ and Bright $|B\rangle = \Omega_d|c\rangle + \Omega_p|b\rangle$ states
- resonance width ($\sim$ 10kHz) much smaller then natural line width

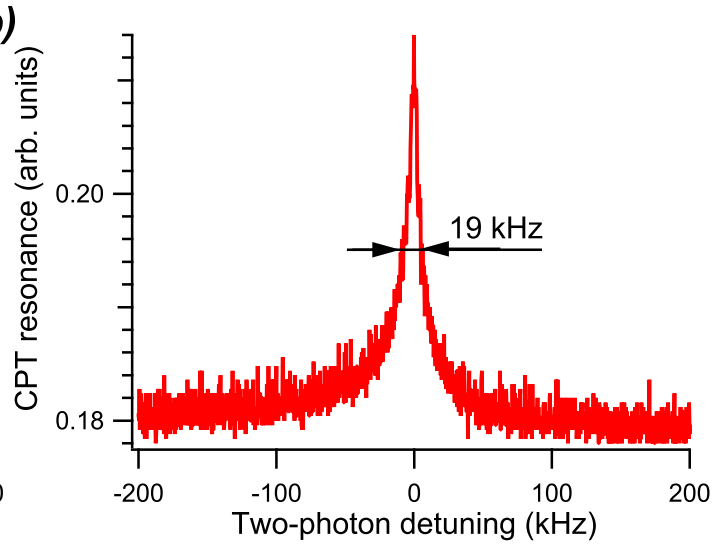
CPT observation



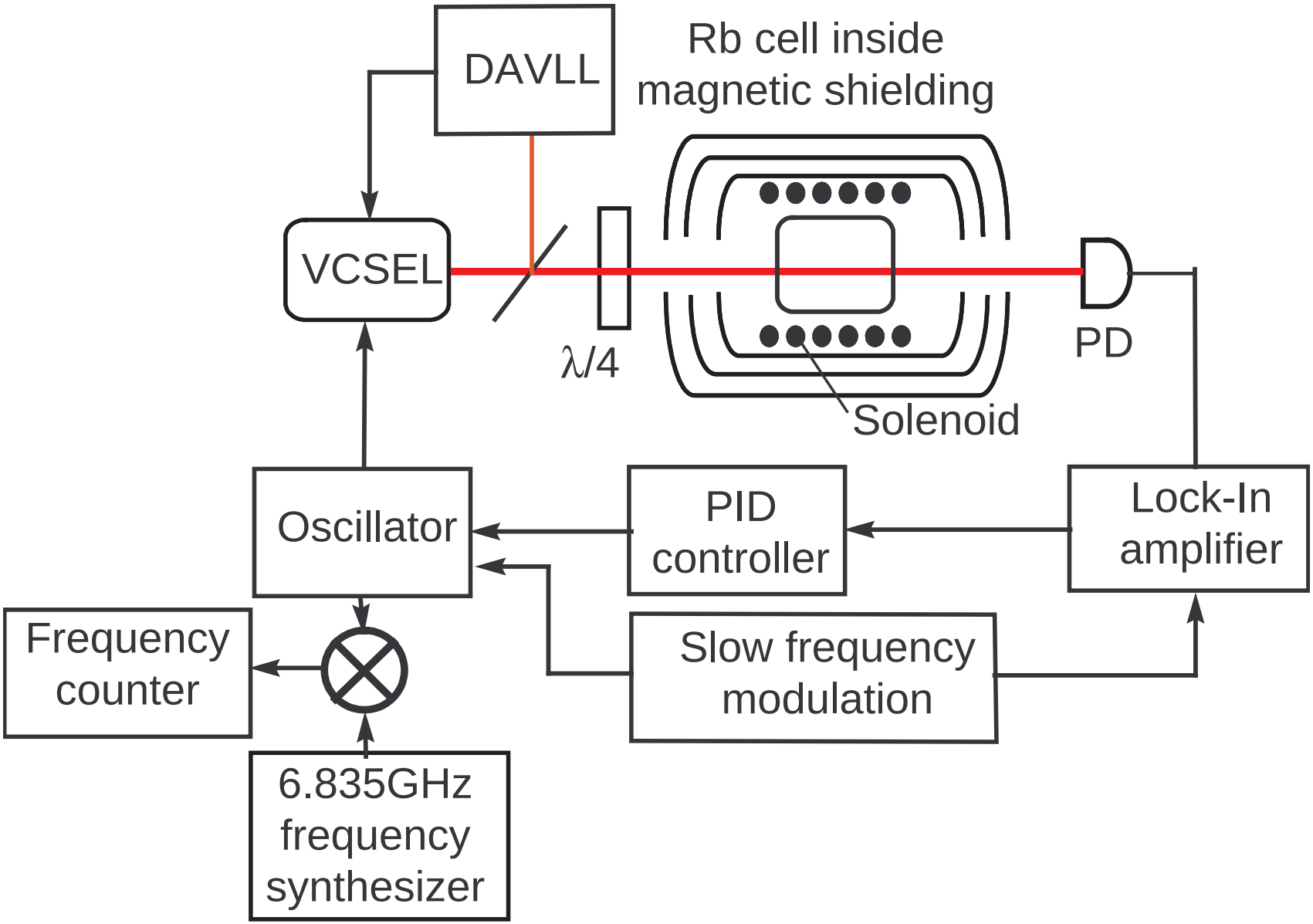






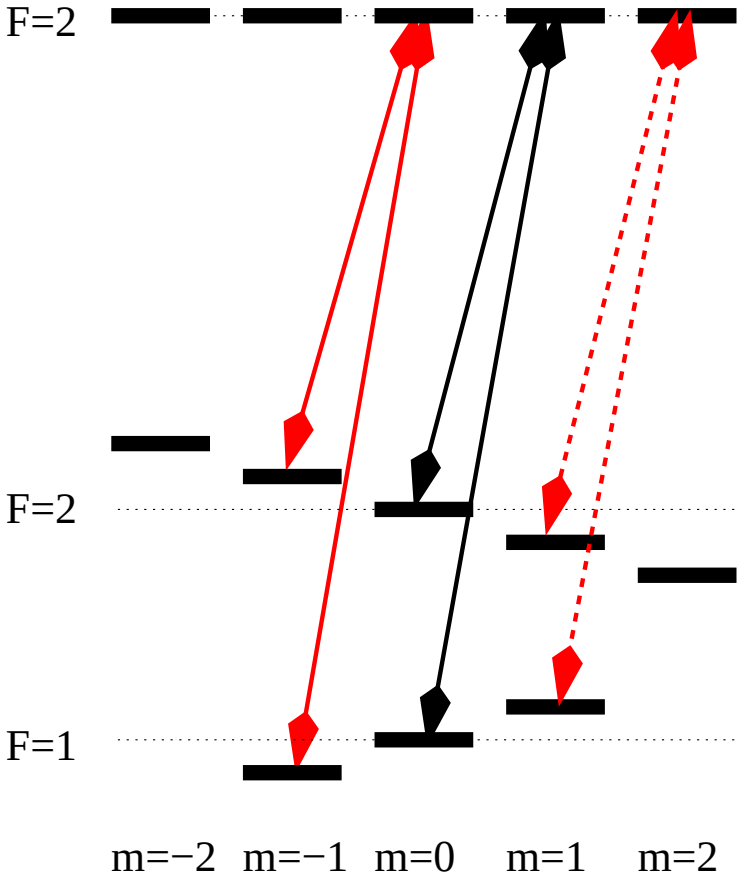


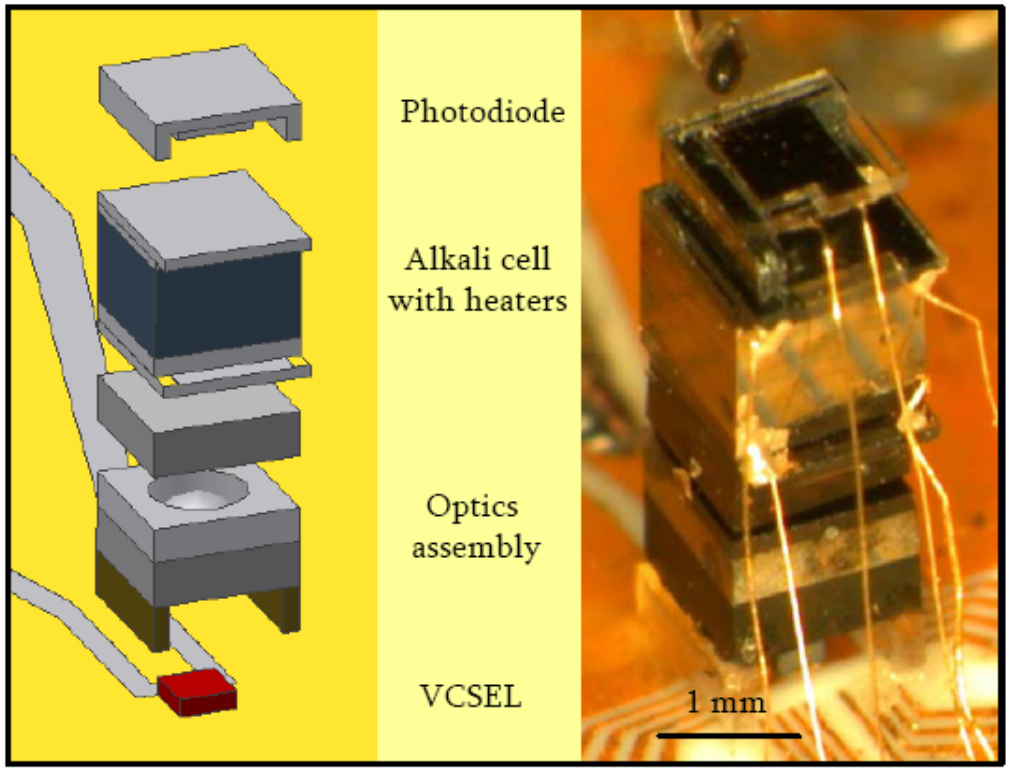
Clock setup


DAVLL
Rb cell inside
magnetic shielding
VCSEL
λ/4
PD
Solenoid
Oscillator
PID
controller
Lock-In
amplifier
Frequency
counter
Slow frequency
modulation
6.835GHz
frequency
synthesizer

There is no 3-level atom and Rb is not one of them

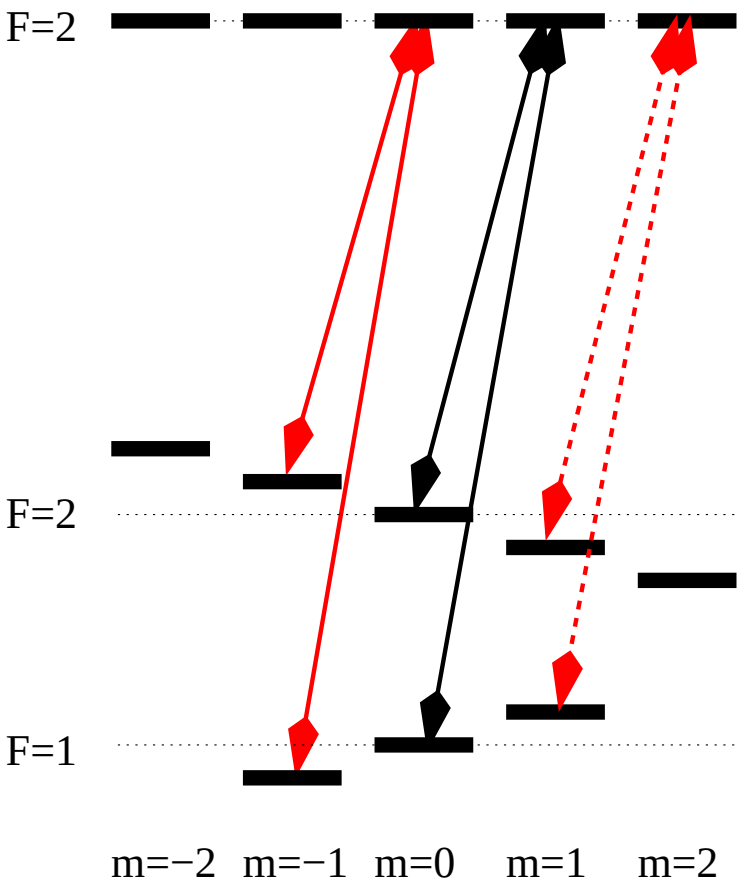
CPT with circularly polarized light

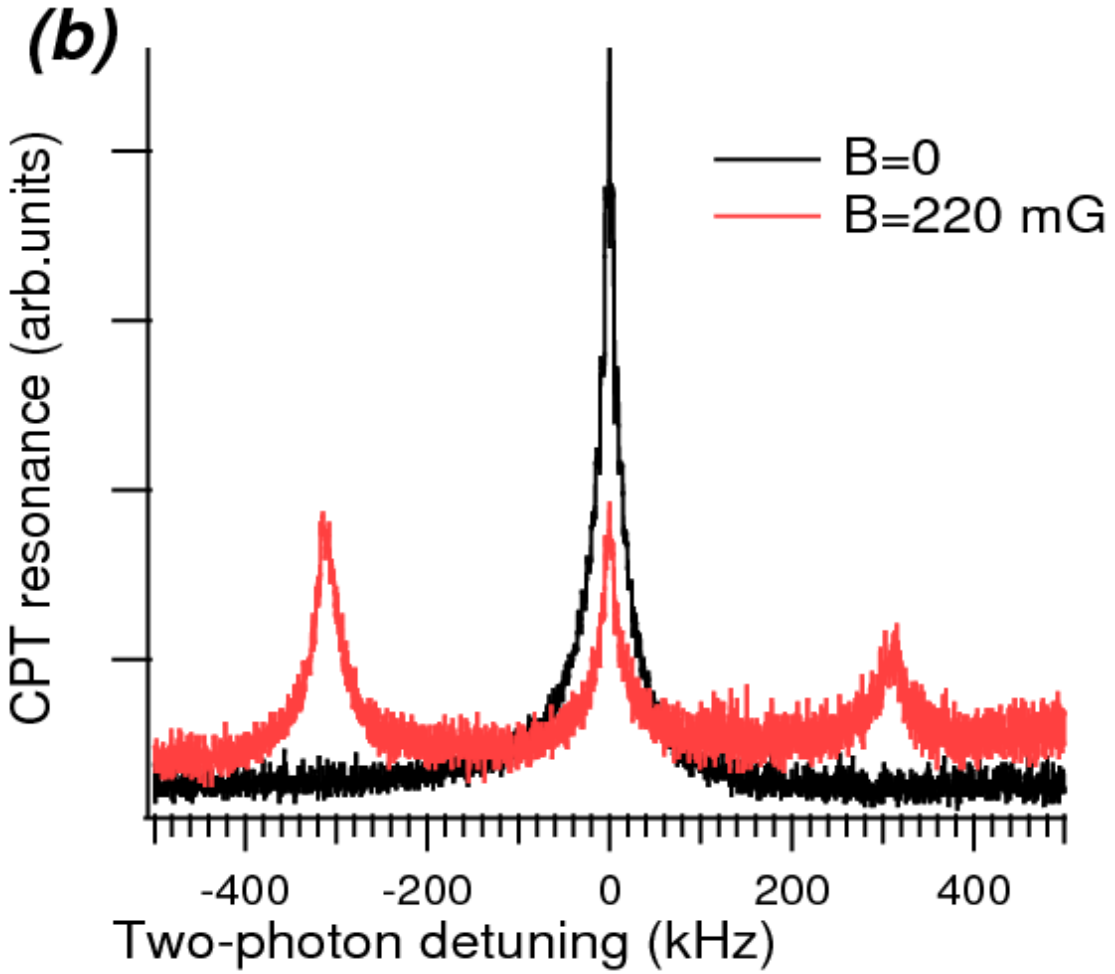




There is no 3-level atom and Rb is not one of them

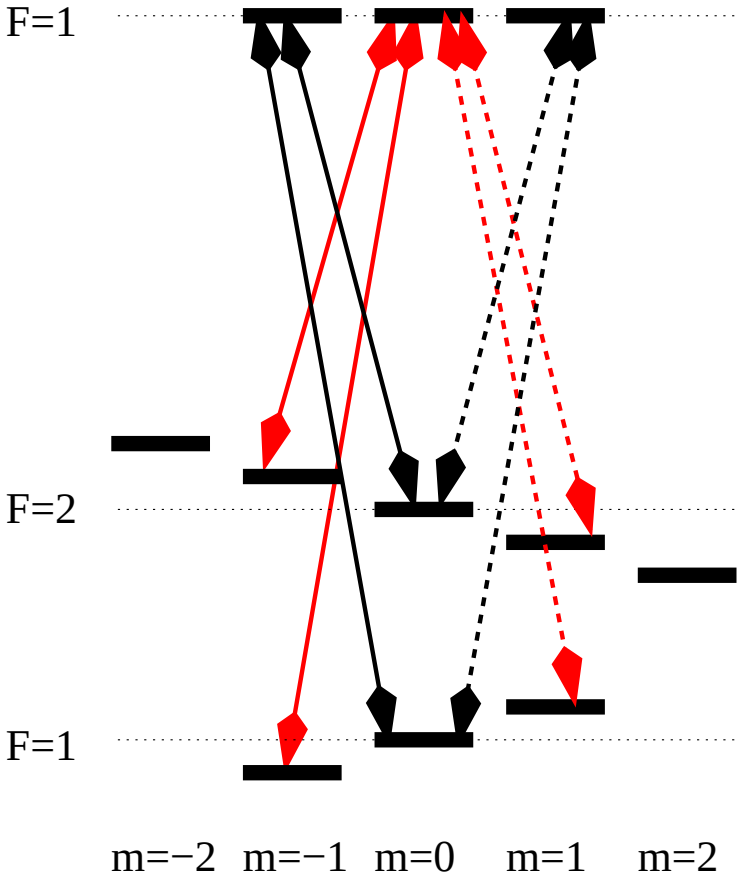
CPT with circularly polarized light

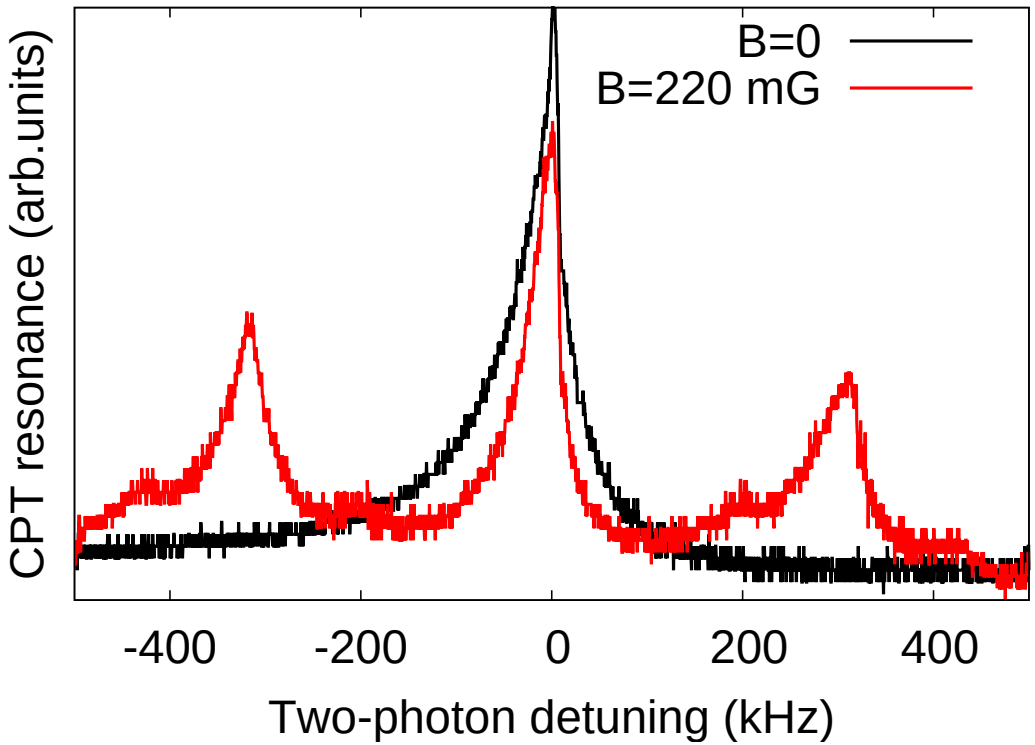




CPT with linearly polarized light

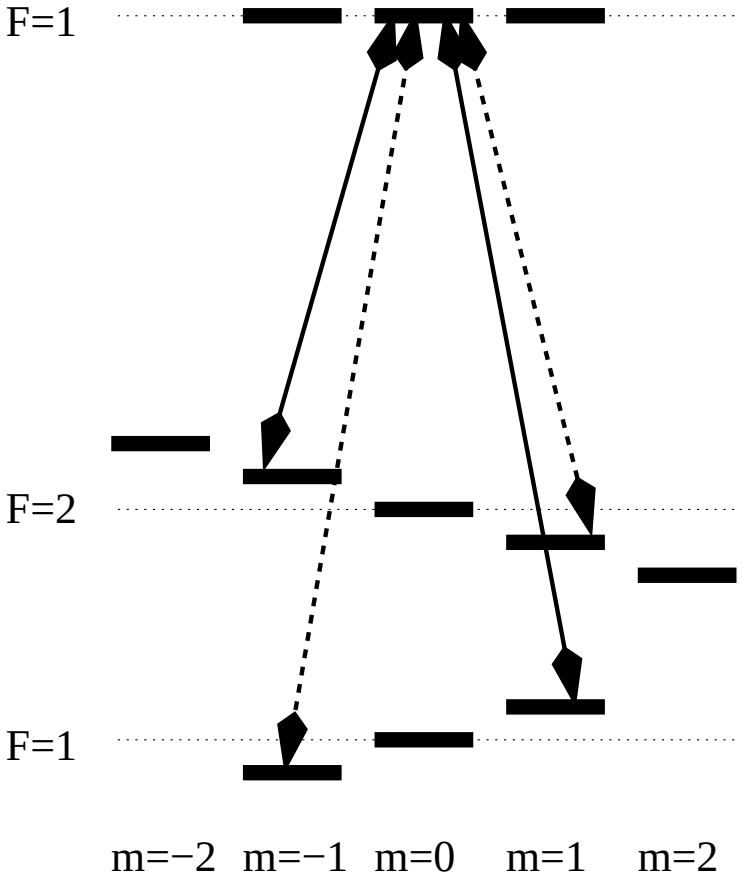
Suggested by A.V. Taichenachev, V.I. Yudin, and S.A. Zibrov

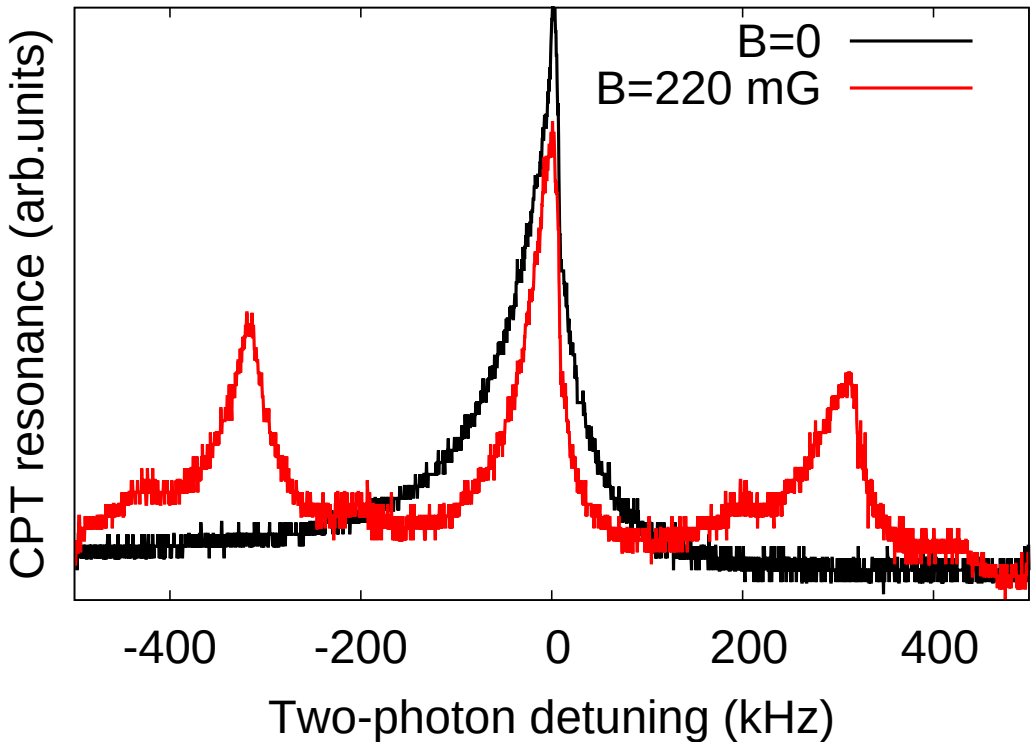




Magneto insensitive CPT with linearly polarized light

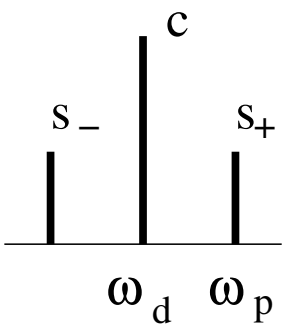
Suggested by A.V. Taichenachev, V.I. Yudin, and S.A. Zibrov

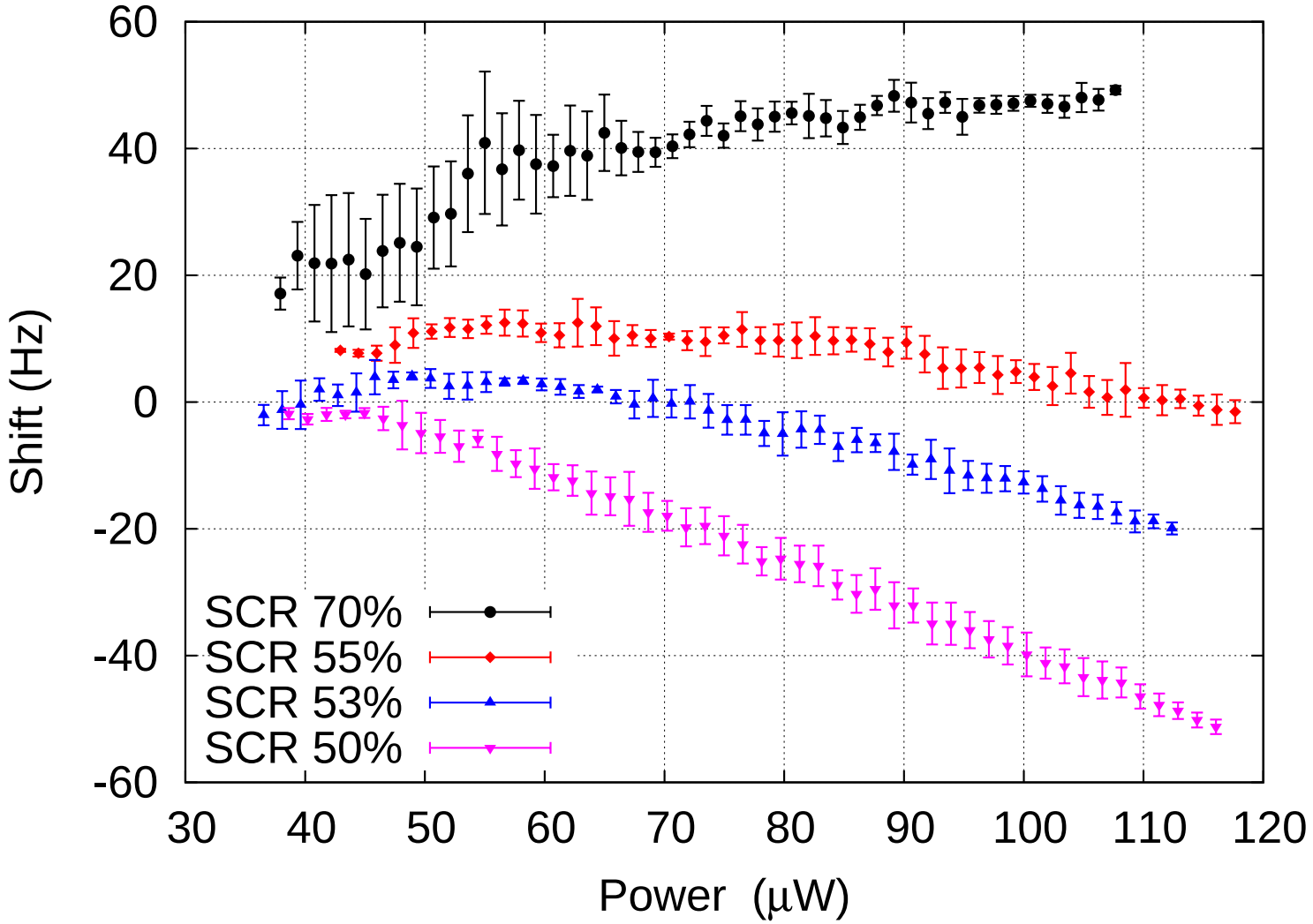




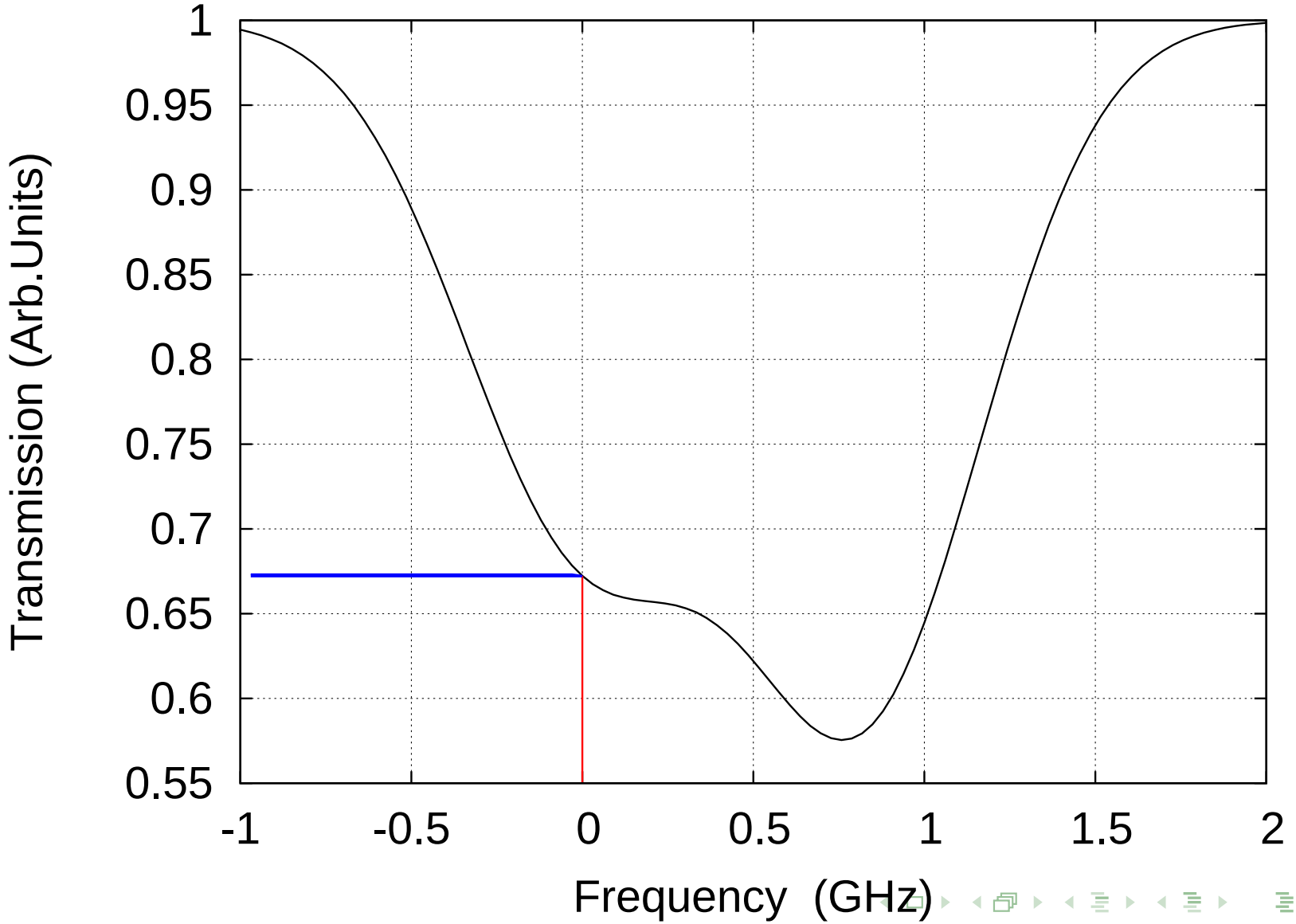
Light shift vs laser power (^{87}Rb, 5T of Ne, $F_e = 1$)

Sideband to carrier ratio SCR=S_+/C

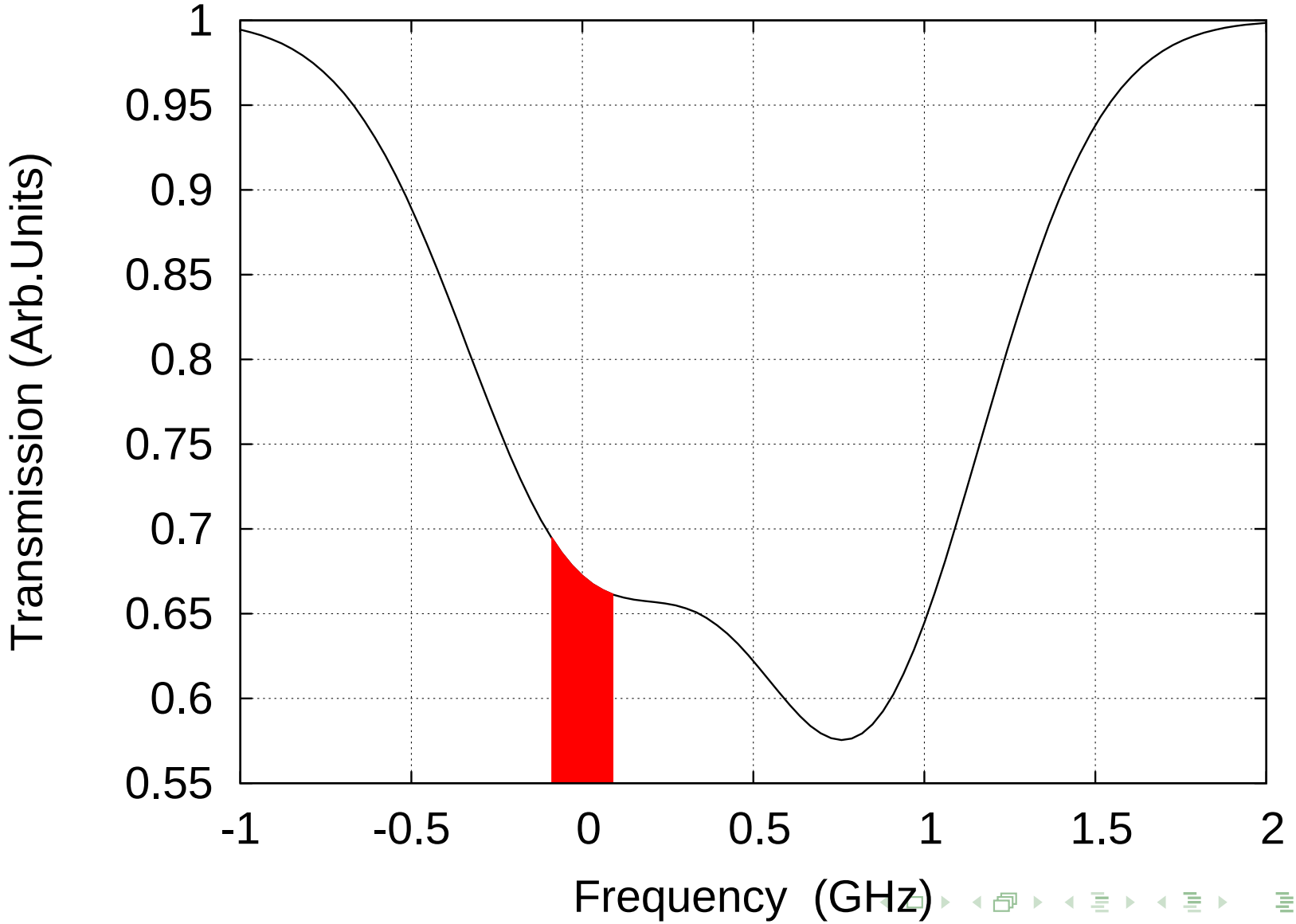




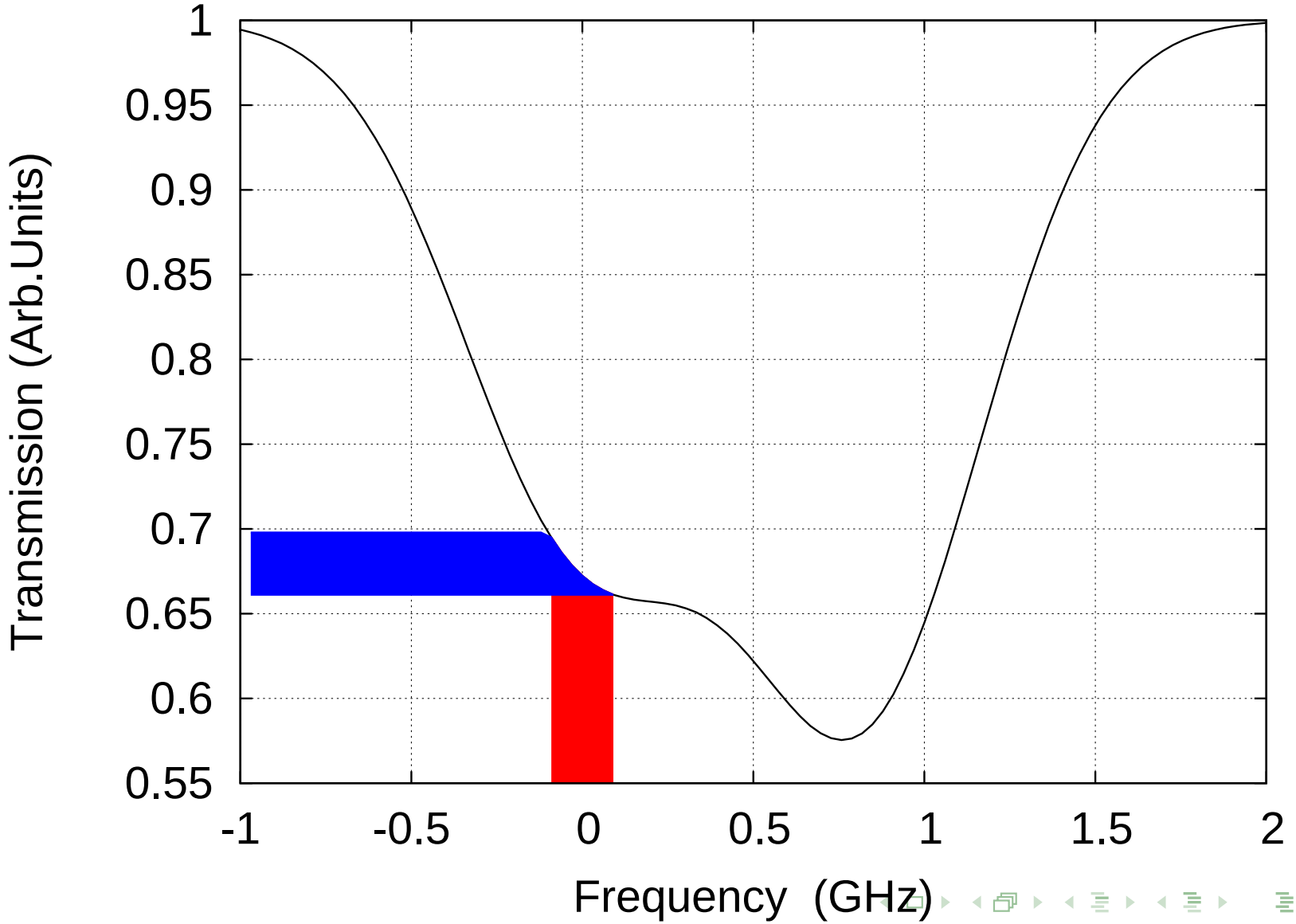
Phase noise to amplitude noise conversion



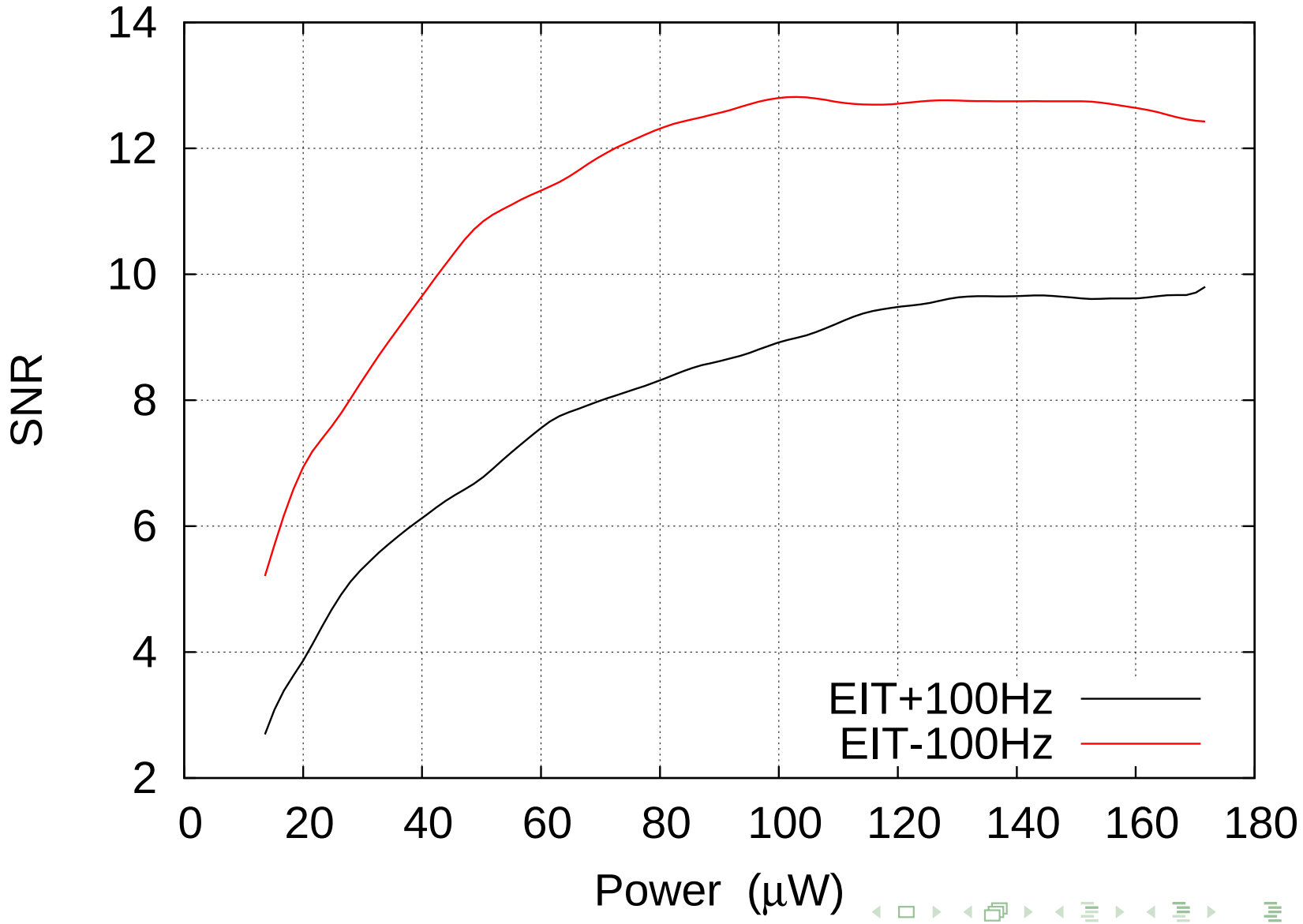
Phase noise to amplitude noise conversion



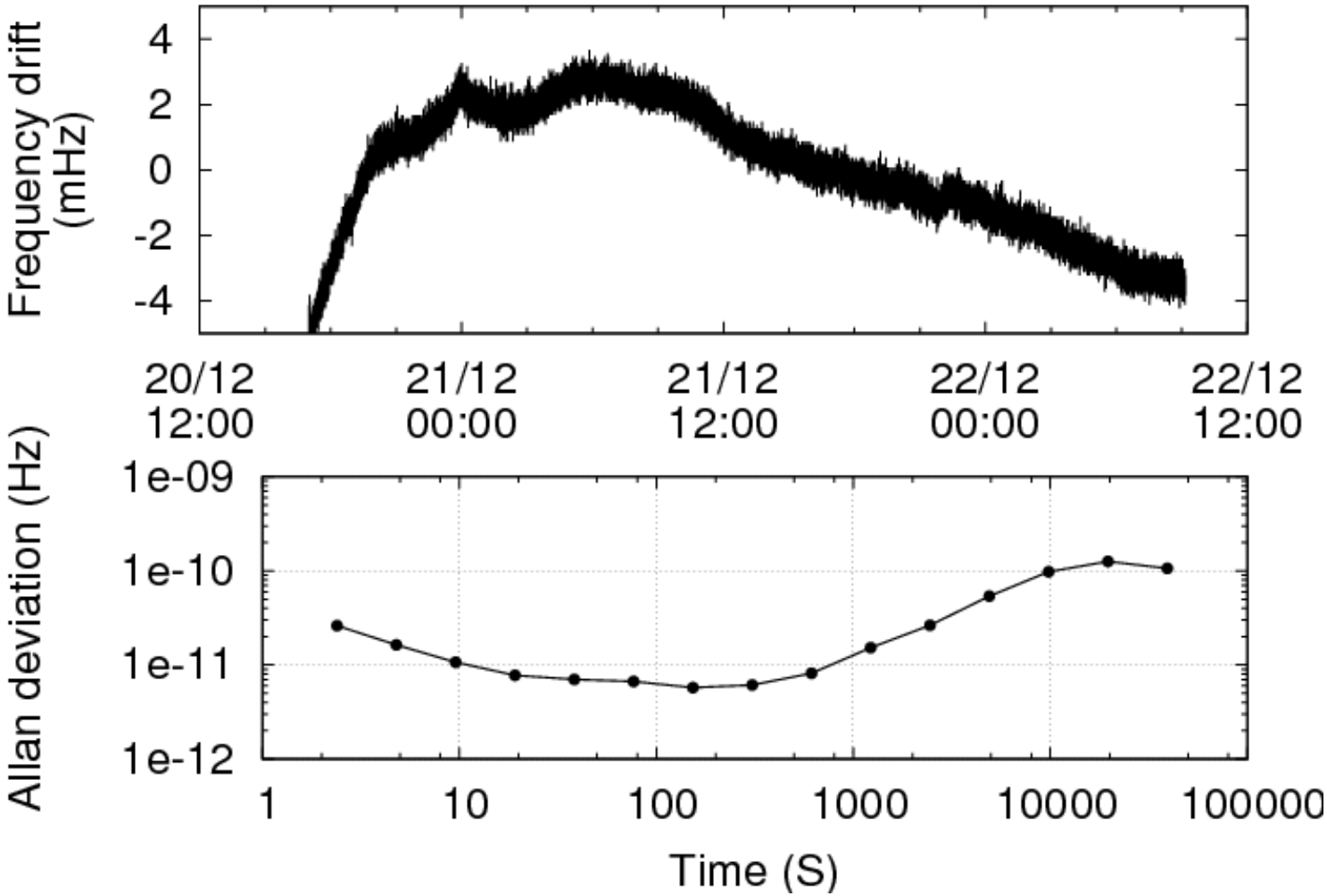
Phase noise to amplitude noise conversion



Clock error SNR vs laser power (^{87}Rb, 5T of Ne, $F_e = 1$)



Stability



Allan deviation of $6 \cdot 10^{-12}$ corresponds to a 1 second per 5000 years clock inaccuracy.

Summary

- Clock in magneto insensitive configuration with Allan deviation of $6 \cdot 10^{-12}$ demonstrated
- Short term stability of the clock is limited by performance of the VCSEL, especially by its phase noise
- for more details: Nathan Belcher, Eugeniy E. Mikhailov, and Irina Novikova **arXiv:0810.2071**