Hot topic presentation

Dynamic Imaging Magnetic Fields with Yb Fluorescence

Hollberg L. H.†, **Na Narong T.**, **Li H.**, **Tong J.**, **Duenas, L.**,
Stanford University, Dept. of Physics and Dept. of Geophysics, Stanford, CA, USA

†leoh@stanford.edu

We observe unexpected dark stripes in bright green fluorescence from the $^1S_0 - ^3P_1$ transition (556 nm) in a Yb atomic beam when excited by two (or more) resonant fields. This occurs when the two fields are resonant with Zeeman-split levels in the $^3P_1$ state and both fields are "strong" relative to the saturation intensity (rather small Isat=136 μW/cm^2), Fig.1. In magnetic field gradients the dark-lines are contours of constant magnetic field. The $^3P_1$ lifetime, 875 ns enables both good spatial resolution ($\sim$100 μm) and rapid ($\sim$10 μs) imaging of magnetic field dynamics with simple cameras. The dark stripes are reminiscent of the well-known CPT and EIT. But for Yb even isotopes in the V-configuration these dark lines result from different physics: predominantly the Autler-Townes AC-Stark splitting at all fields and at low fields the spatial Hanle effect.[1,2]

Experimental images guided our development of a theoretical model for the closed 4-level $^1S_0 - ^3P_1$ transition that is driven by multiple "strong" optical fields, including the Zeeman structure and Doppler broadening. With the model and images, it's possible to make scalar and vector magnetic field measurements at video frame rates over spatial dimensions of 5 cm (feasible up to meter) with 0.1 mm resolution. Two videos here [3] illustrate some unique capabilities of this Yb imaging magnetometer. This model allows direct computation of magnetic field tomography from images collected in experiments as well as generation of fluorescence images given B-field input. In principle, this Yb transition allows for $\sim$ μs response times and a spatially imaging magnetic fields with a large dynamic range (from micro-tesla to many tesla).

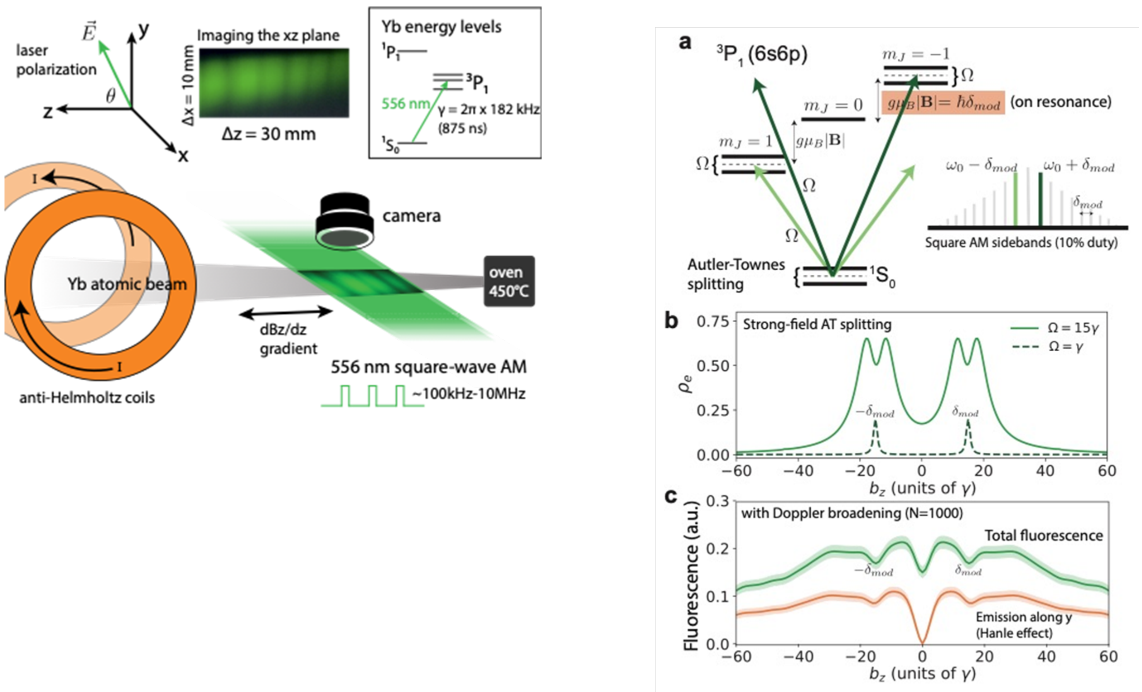

Figure 1: 1) Simple experimental system: Yb atomic beam, probed by a sheet of resonant laser modulated in time, camera, and magnetic field gradient. a) $^3P_1$ levels split by Zeeman and Autler-Townes splitting on all three resonant V- levels. b) calculated fluorescence as function of lBl for two fixed frequency sidebands, both weak vs. strong, c) adding Doppler averaging. The central feature near lBl=0 is due to the spatial Hanle effect.

[1] T. Na Narong, H.Li, J. Tong, M. Duenas, L. Hollberg, accepted for publication Phys Rev. Letts, (Apr. 2025), and https://doi.org/10.48550/arXiv.2411.14426 . and videos ref. 3 below.

[2] Tanaporn Na Narong, PhD thesis, Stanford University (2023).

[3] https://drive.google.com/drive/folders/12Kyw5_sI6B8Sh832fMSA5XTkmiKxCQfN?usp=drive_link