DIAMOND SENSOR FOR THE NEUTRON ELECTRIC DIPOLE MOMENT EXPERIMENT

Chris Hovde
Southwest Sciences Inc
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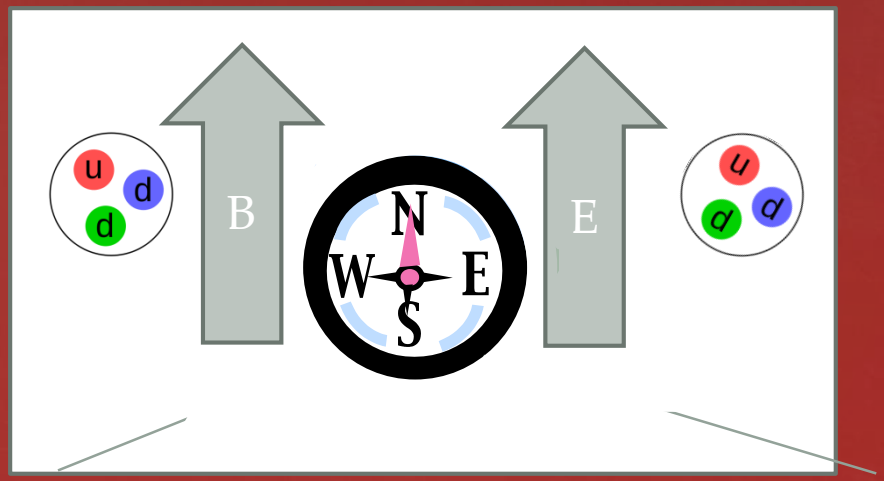
Southwest Sciences is a small business founded to perform research and develop technology in combustion, atmospheric chemistry, imaging, and optical sciences.

>30 patents
>200 papers
5 active licenses
Offices in Santa Fe and Cincinnati

For nEDM applications, field sensors are used to test field homogeneity and stability before and during operation

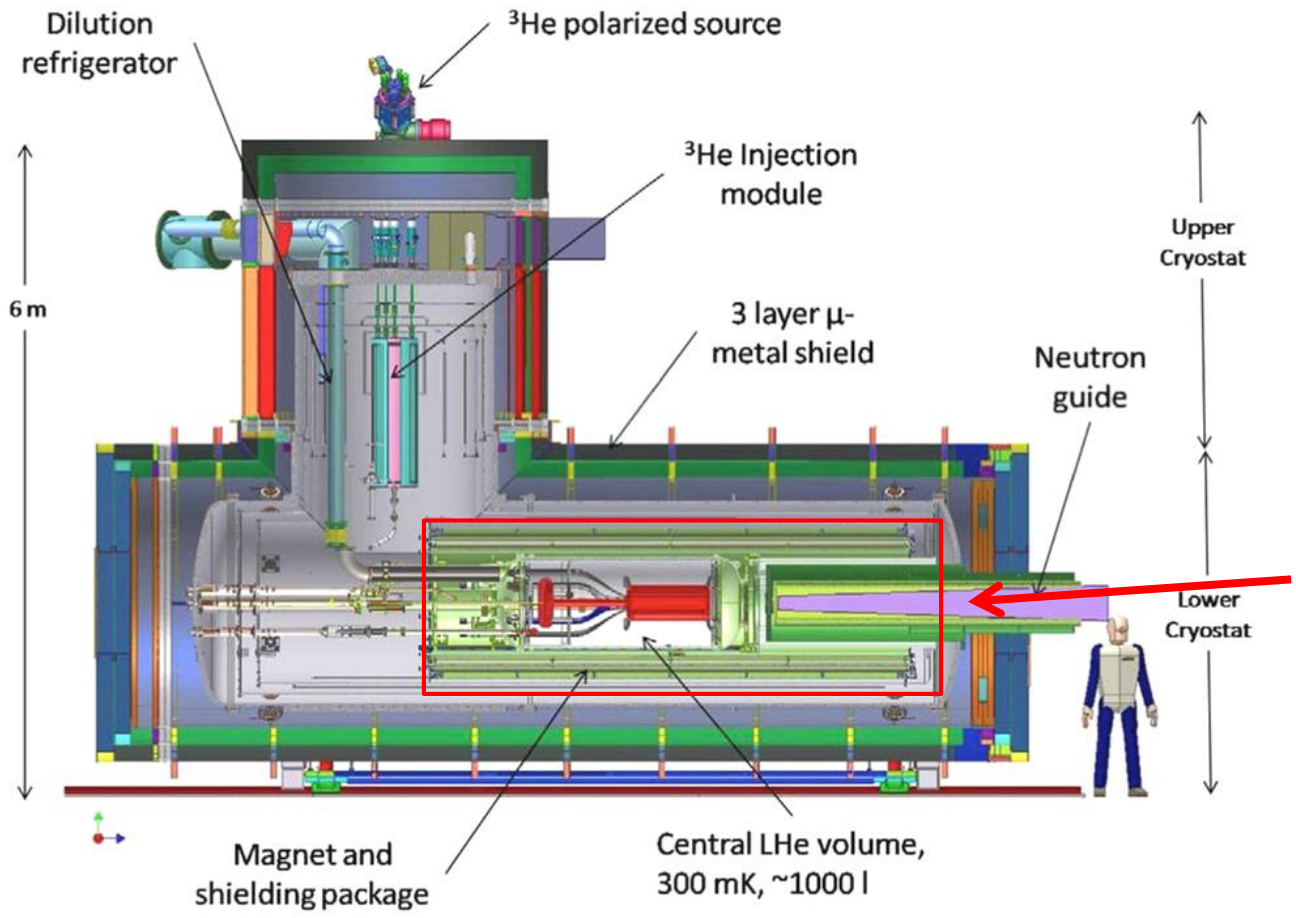
Measure rotation of polarized neutron spins by combined magnetic and electric fields



Atomic magnetometers operating at room temperature (Scalar or Vector)

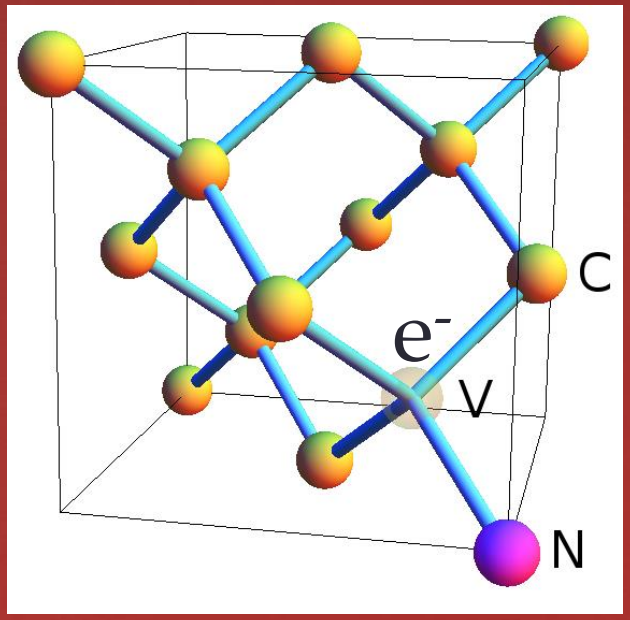
Diamond electrometer/magnetometers operating at cryogenic temperature (Vector)

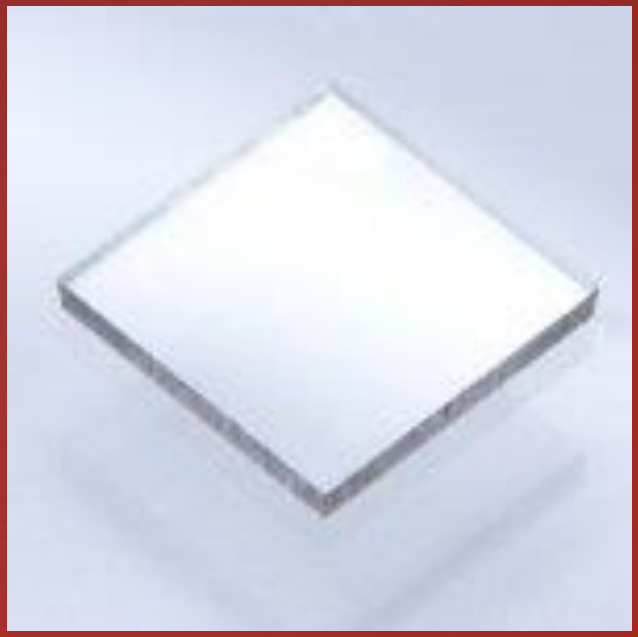
nEDM expts need instruments that are sensitive, stable, non-perturbing, can fit tight spaces



Limited access to field region

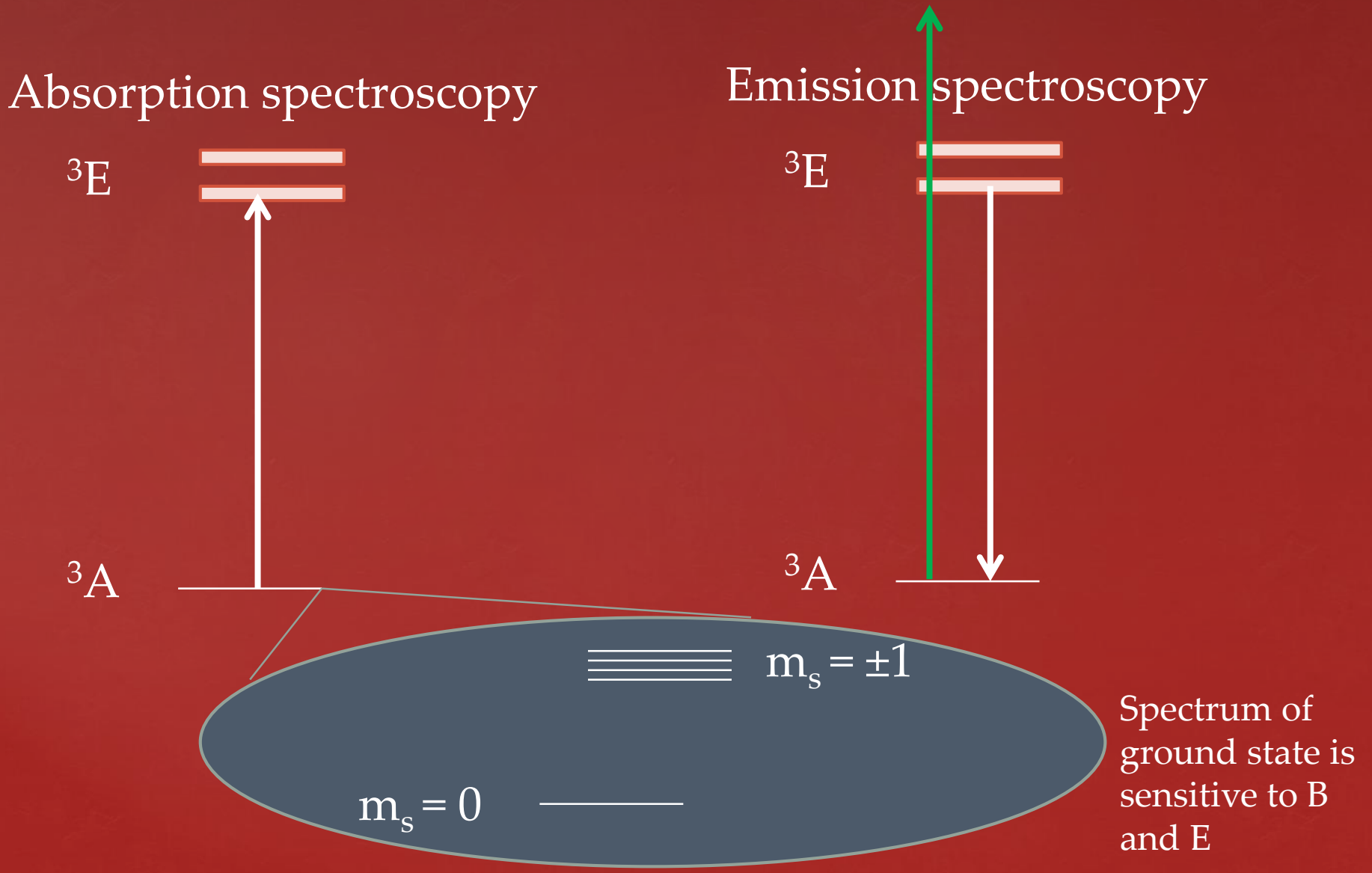
Diamonds produced by chemical vapor deposition feature high purity, controlled doping.





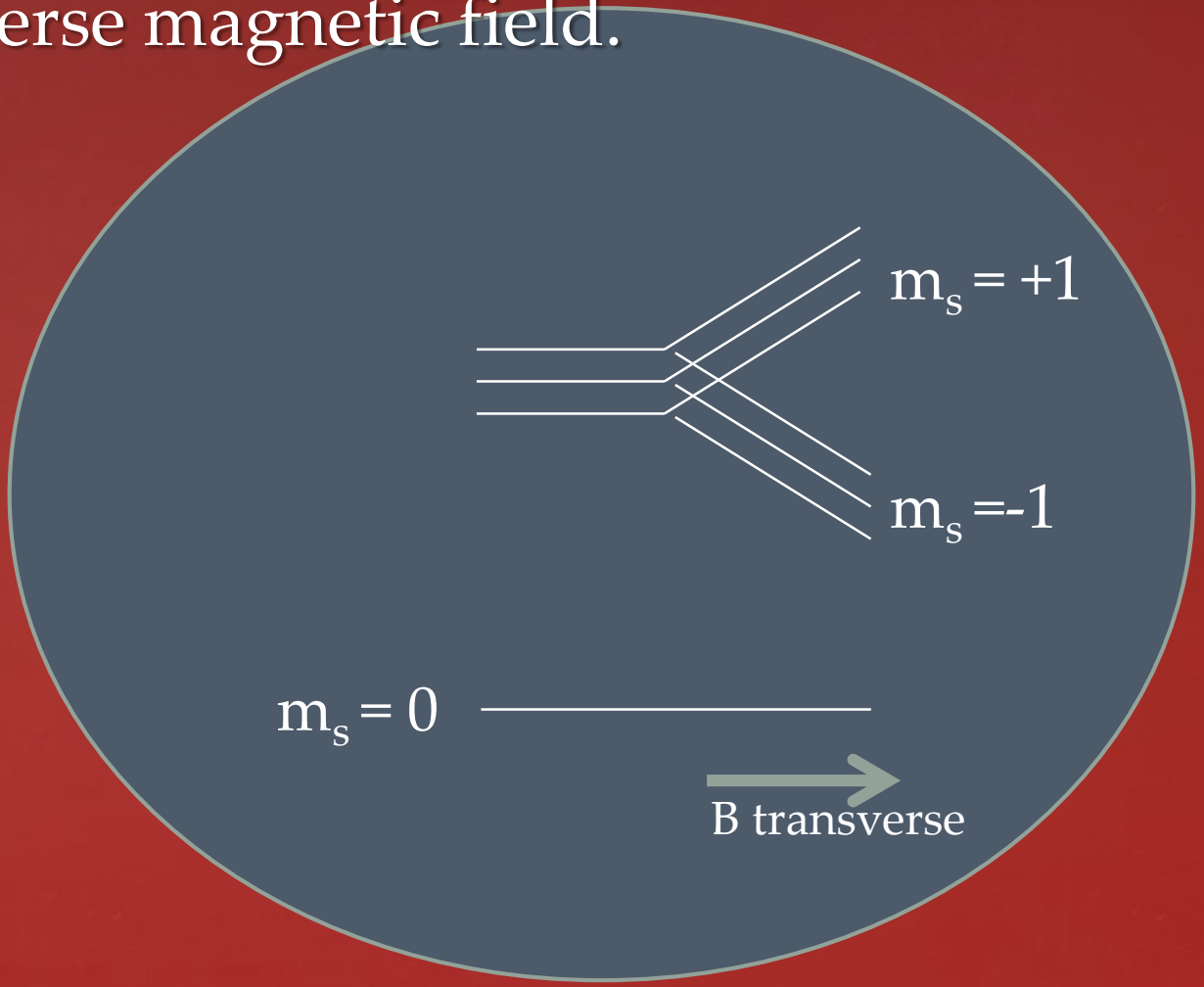
Start with ppm level of nitrogen. Bombard with electrons to make vacancies, then anneal to pair N and V. Add electron to form NV^- Single crystal diamonds 5x5x0.5 mm cost about $600.

NV diamond spectroscopy allows optical detection and high spectral resolution

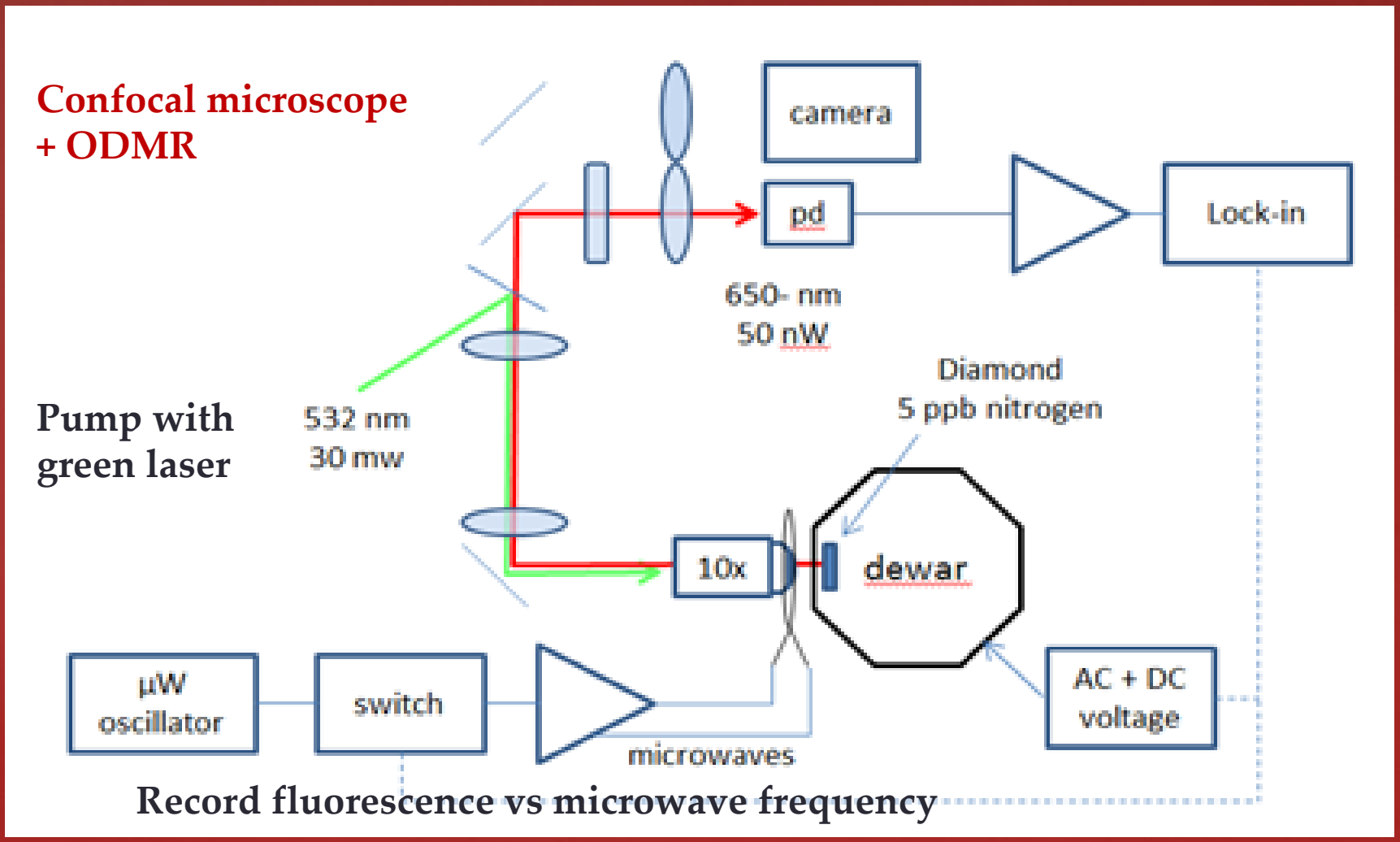


Spectrum of ground state is sensitive to B and E

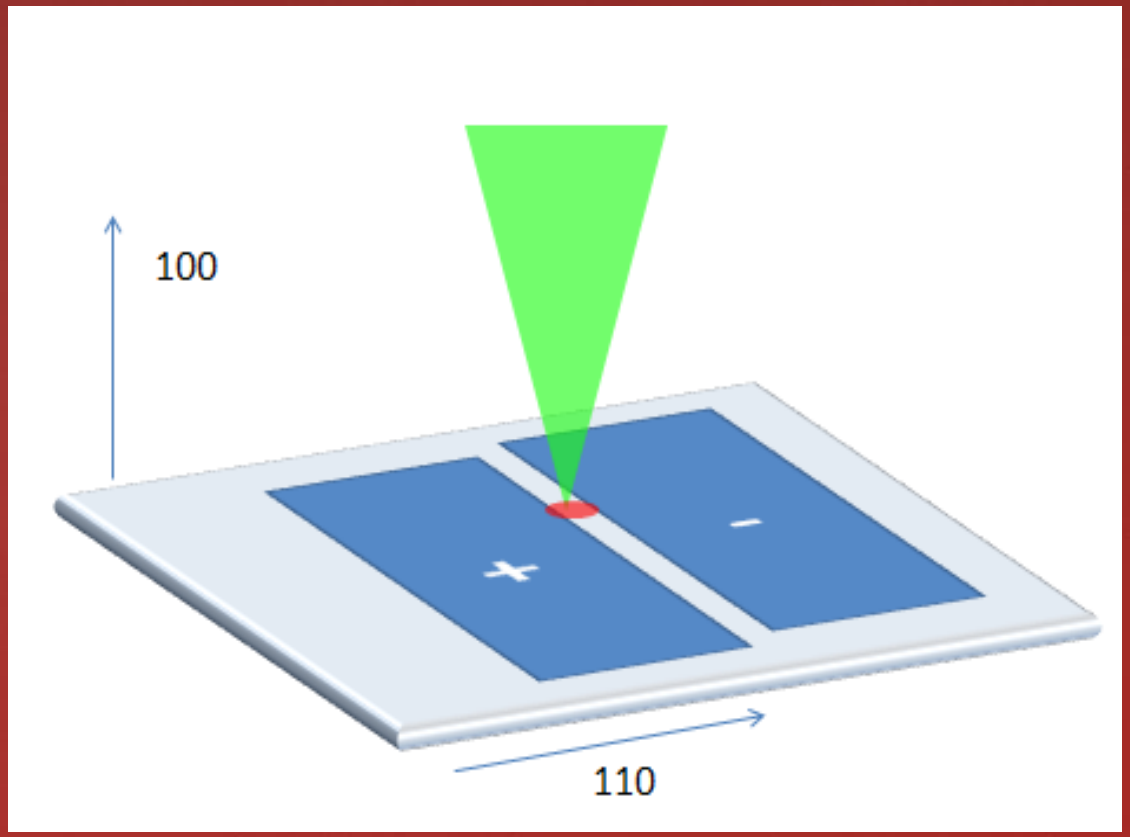
Magnetic field tuning depends on longitudinal component of magnetic field; electric tuning depends on transverse component and transverse magnetic field.



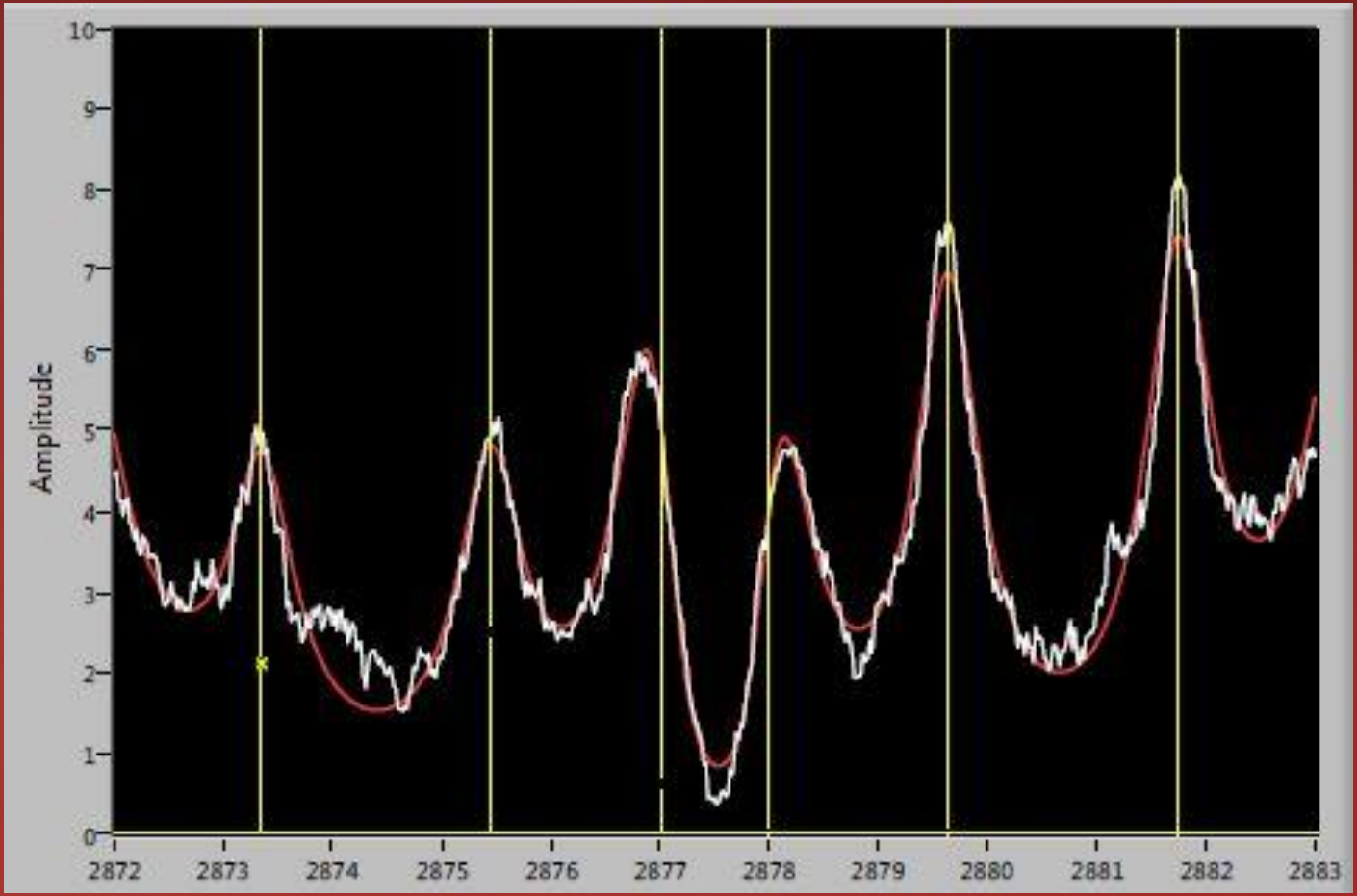
Optically-detected magnetic resonance can detect ground state spectrum



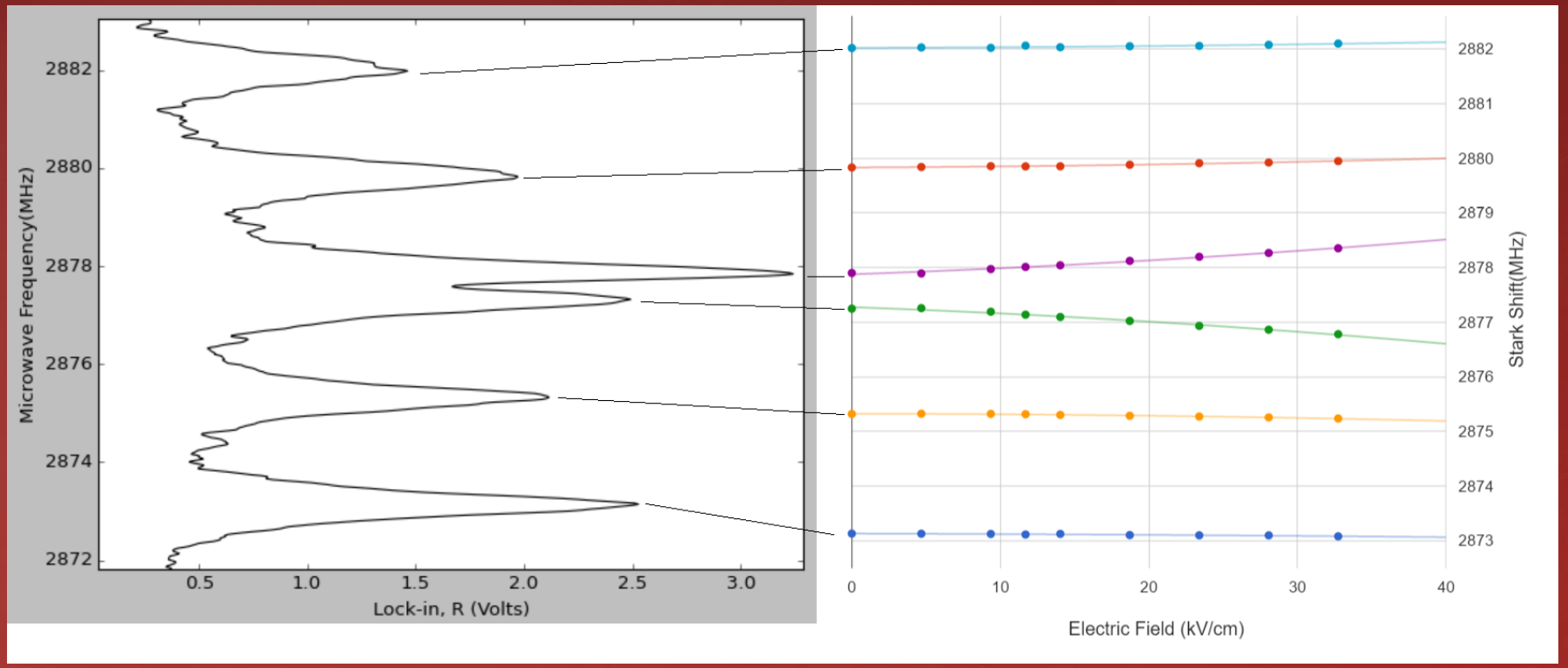
Diamond with electrodes printed on the top face



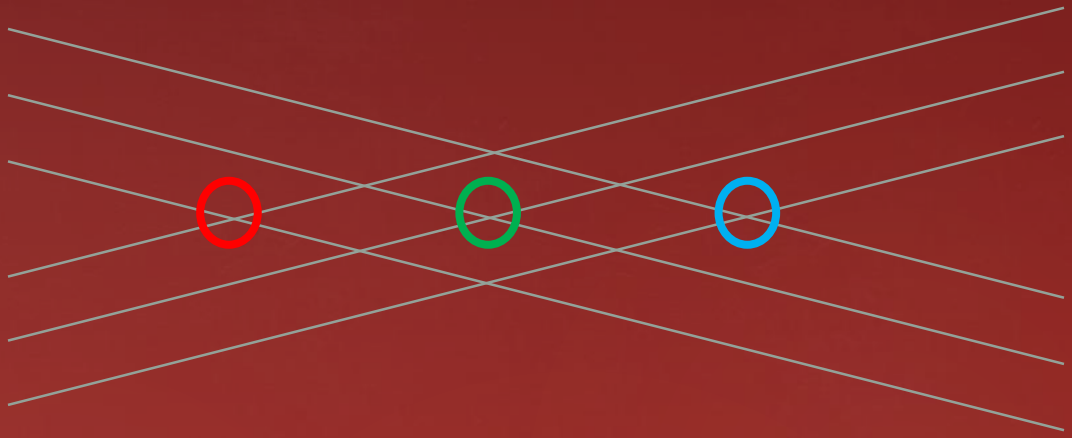
Electrodes courtesy of Hemmer group at TAMU

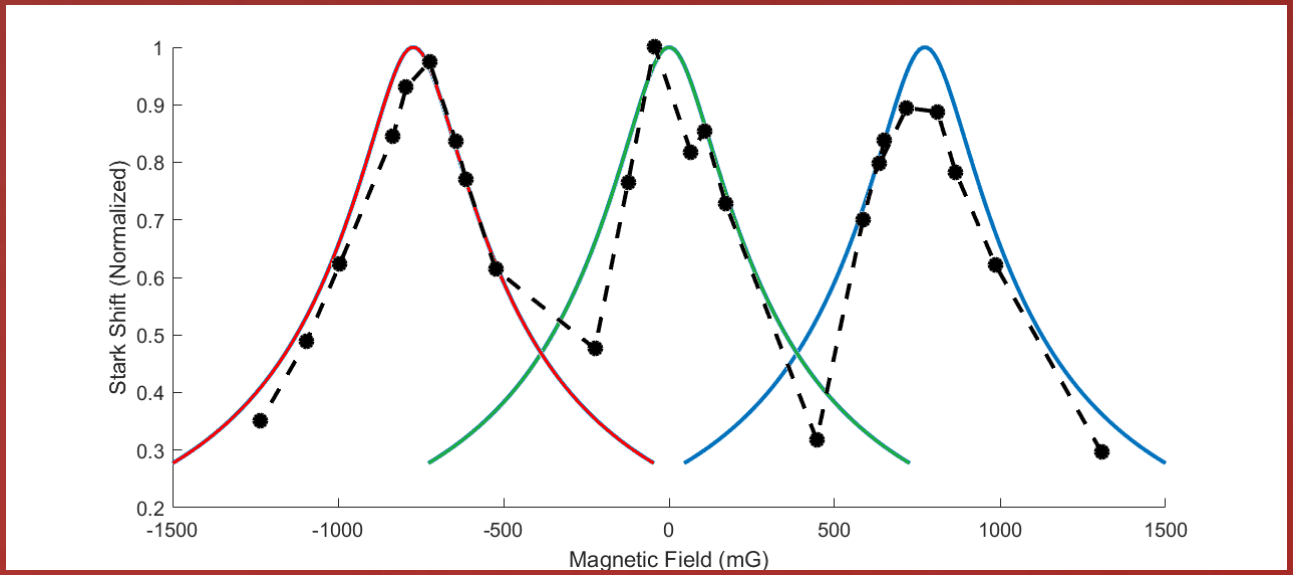


Typical spectrum on an NV center consists of a number of spectral lines due to electron spin and nuclear spin

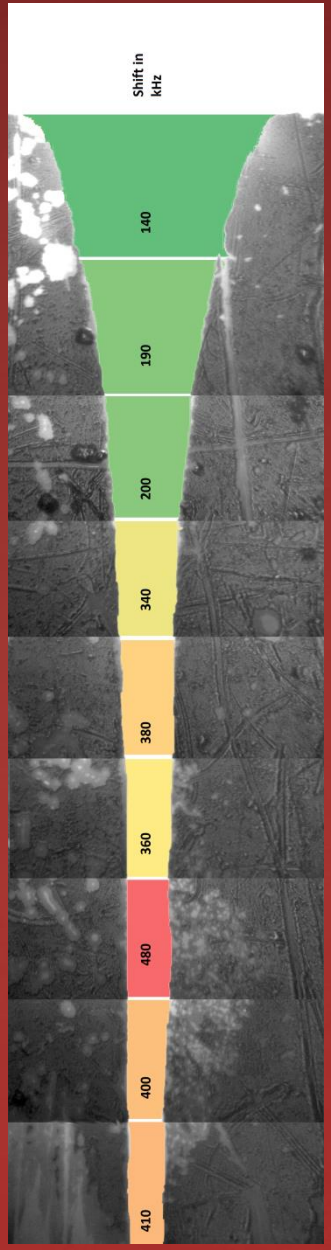


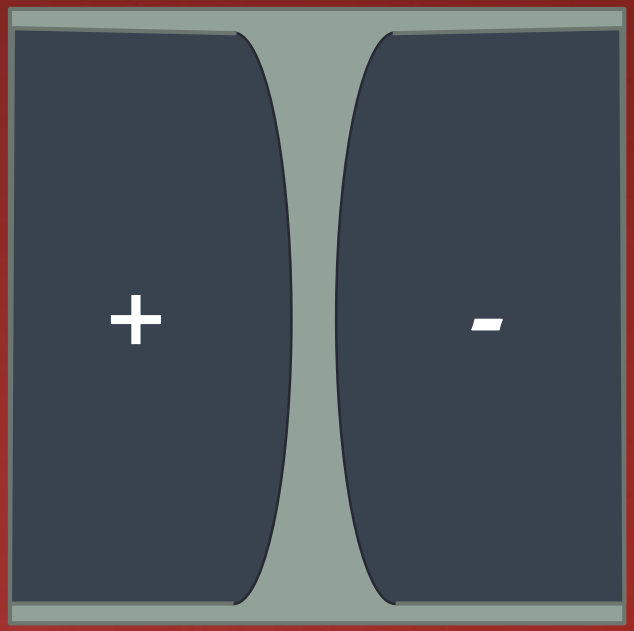
Electric fields shift resonances slightly (~100 kHz)





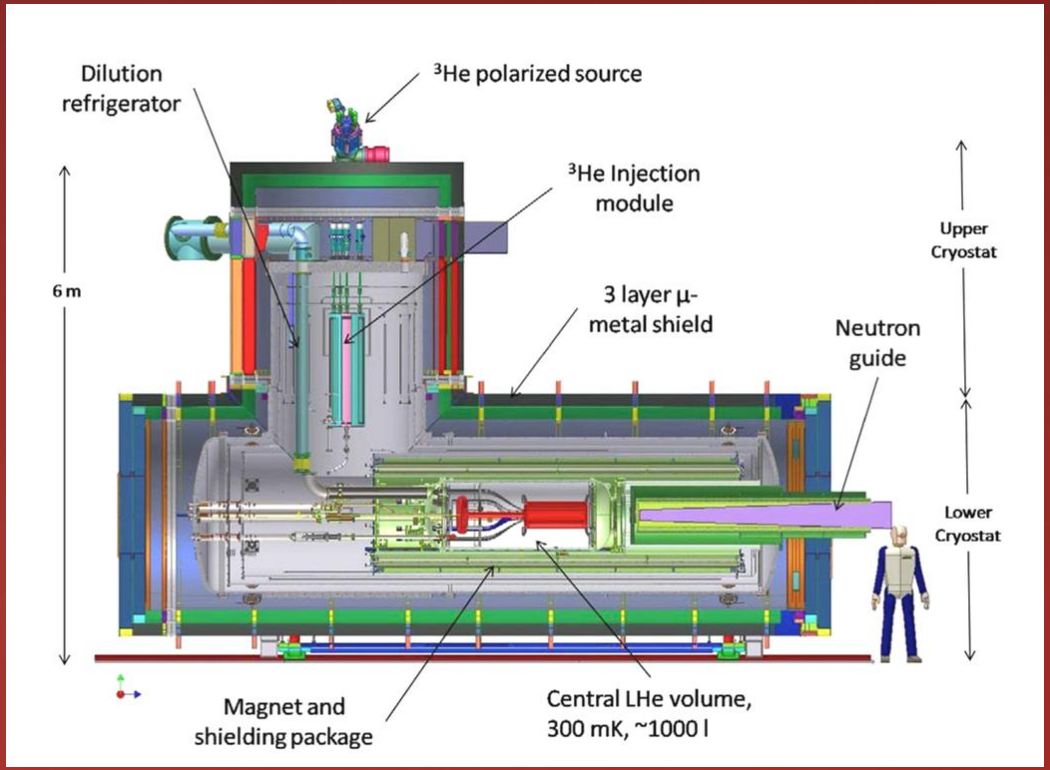
Large electric field effects are observed at 0 and ±80 uT





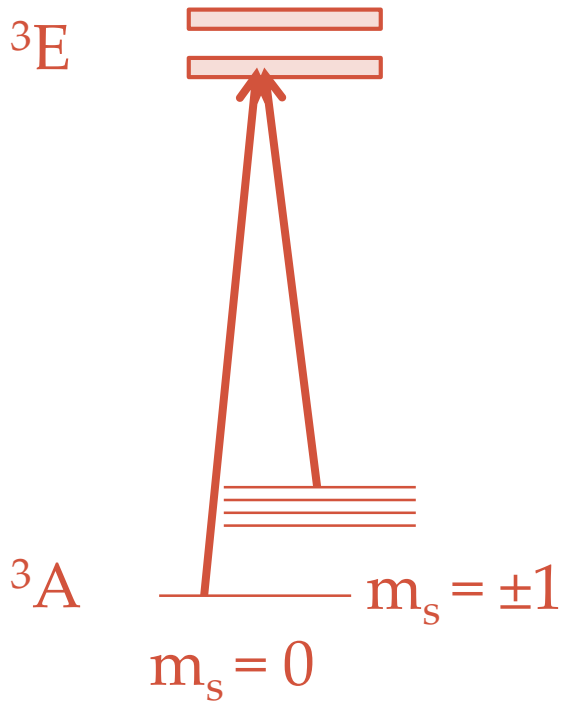
The electric field can be imaged. Quantitative vector info requires additional analysis.

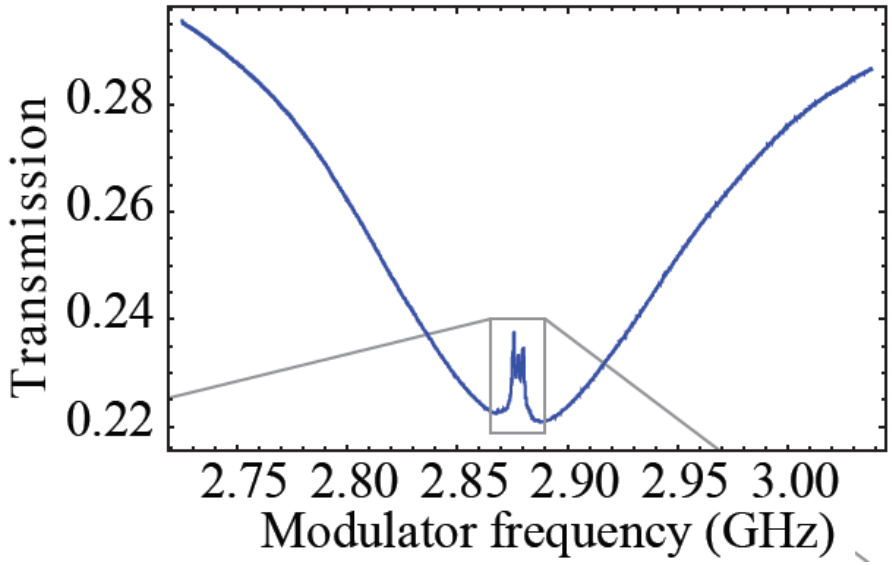
But……



ODMR requires microwaves. We want an all optical technique. Can use EIT or other techniques.

When laser sideband frequency matches ground state splitting, quantum interference reduces absorption





Acosta et al, Phys. Rev. Lett. 110, 213605 (2013)

Works at low temperature with relatively long path (centimeters) through diamond

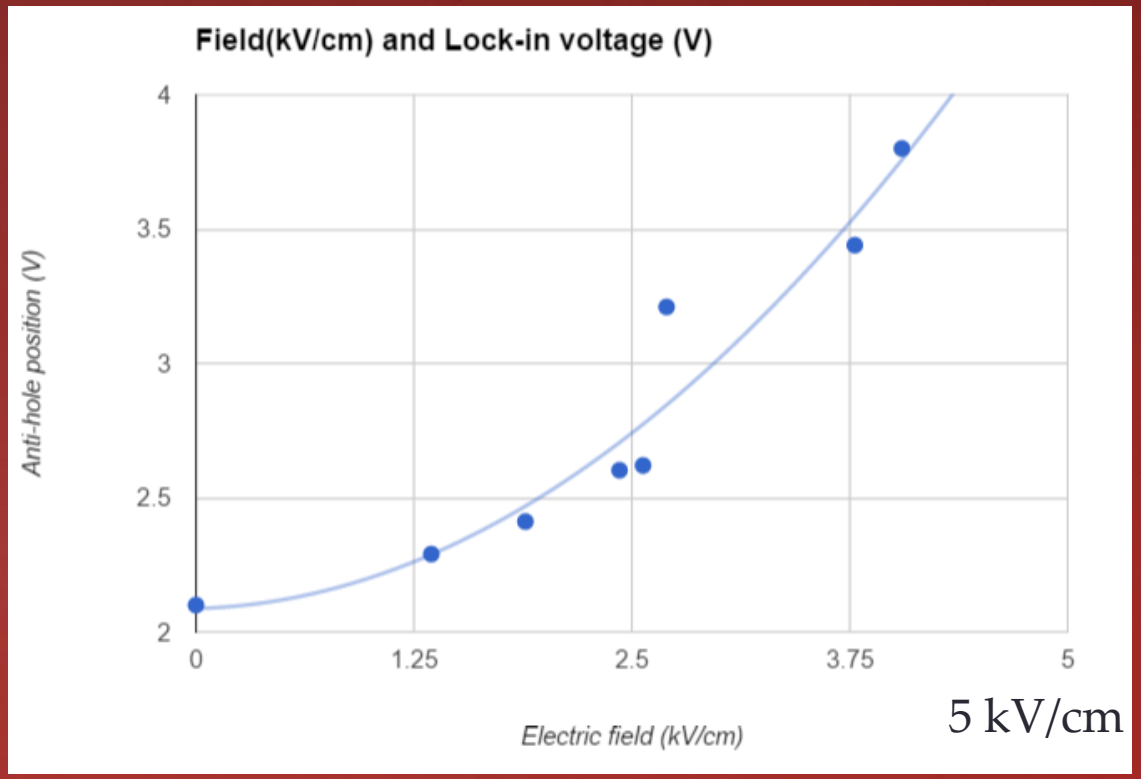
Total internal reflection can provide the long path needed for EIT

Notch on the edge of the diamond to let light in/out

With green filter, red fluorescence is visible to naked eye

Technique outlined in Clevenson et al, arXiv:1406.5235 (2014)

Signal amplitude



Electric Field (kV/cm)

All-optical measurement of electric field using anti-hole amplitude

Conclusions

- NV diamond can be used to sense electric and magnetic fields
- Optically-detected magnetic resonance provides spatial resolution, works from room temperature to cryogenic temperatures
- Working to quantify field from spectrum
- All optical techniques are possible: EIT and even anti-hole detection