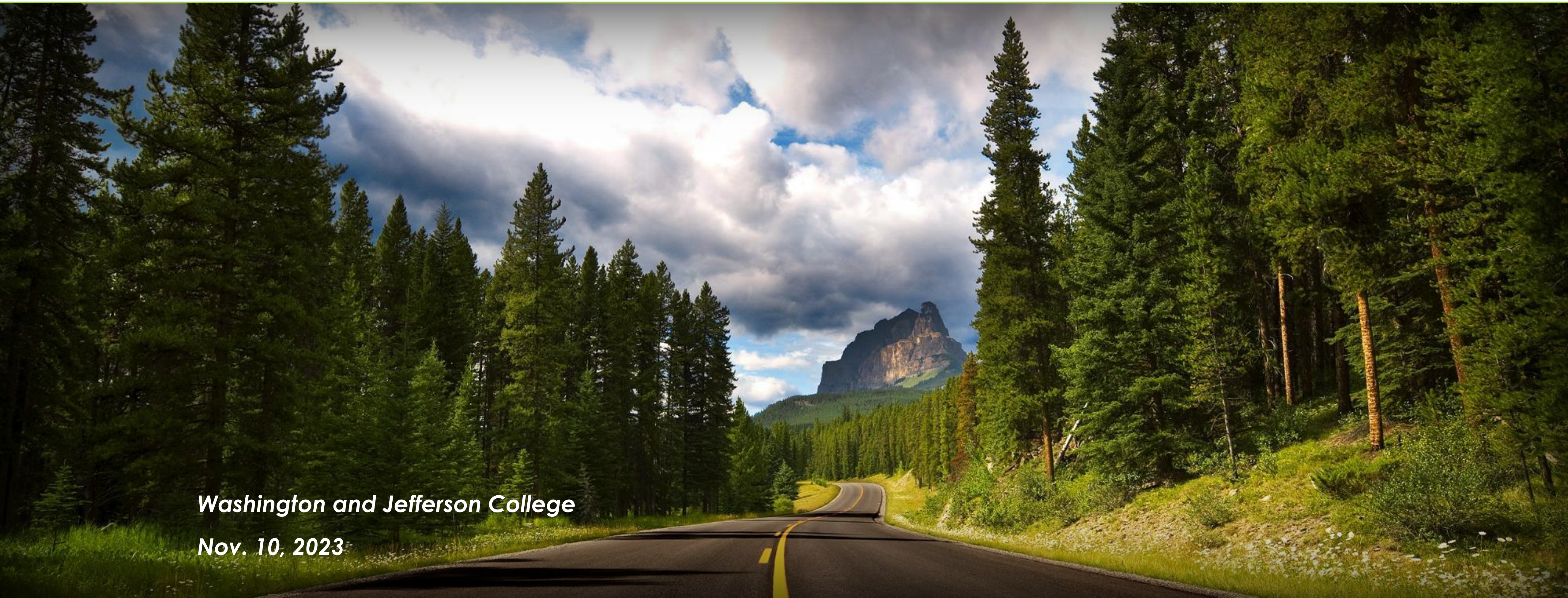
Research as an Experimental Physicist and Optical Engineer at NETL

Gary Lander
NETL Support Contractor



Washington and Jefferson College

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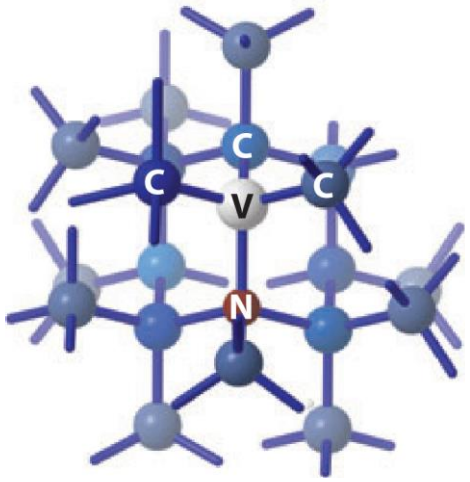
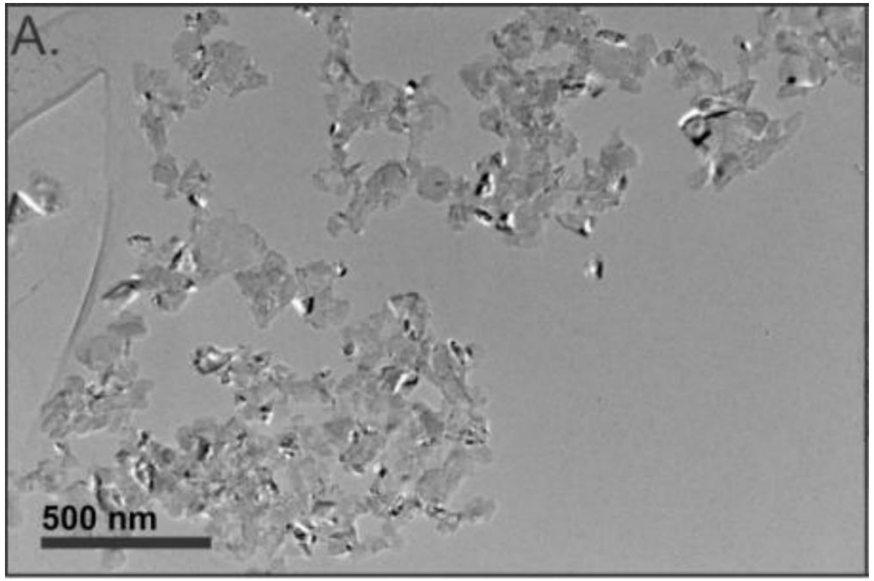
Optically Detected Magnetic Resonance (ODMR) and Spin Relaxometry Using NV Centers in Nanodiamonds

Motivation

- Quantum sensors are more sensitive than classical sensors
- Nitrogen NV centers in diamond exhibit utilizable quantum properties at room temperature
- Bound electron energy levels and spin relaxation time are dependent on the local environment
- Physical quantities (e.g., magnetic field, electric field, temperature, and strain) affect crystal lattice, which affect energy levels and spin relaxation time
- Measure affects via optically detected magnetic resonance (ODMR) and spin relaxometry
- First, we will use as magnetic field sensor for REE detection





Bound Electron States Depend on Environment

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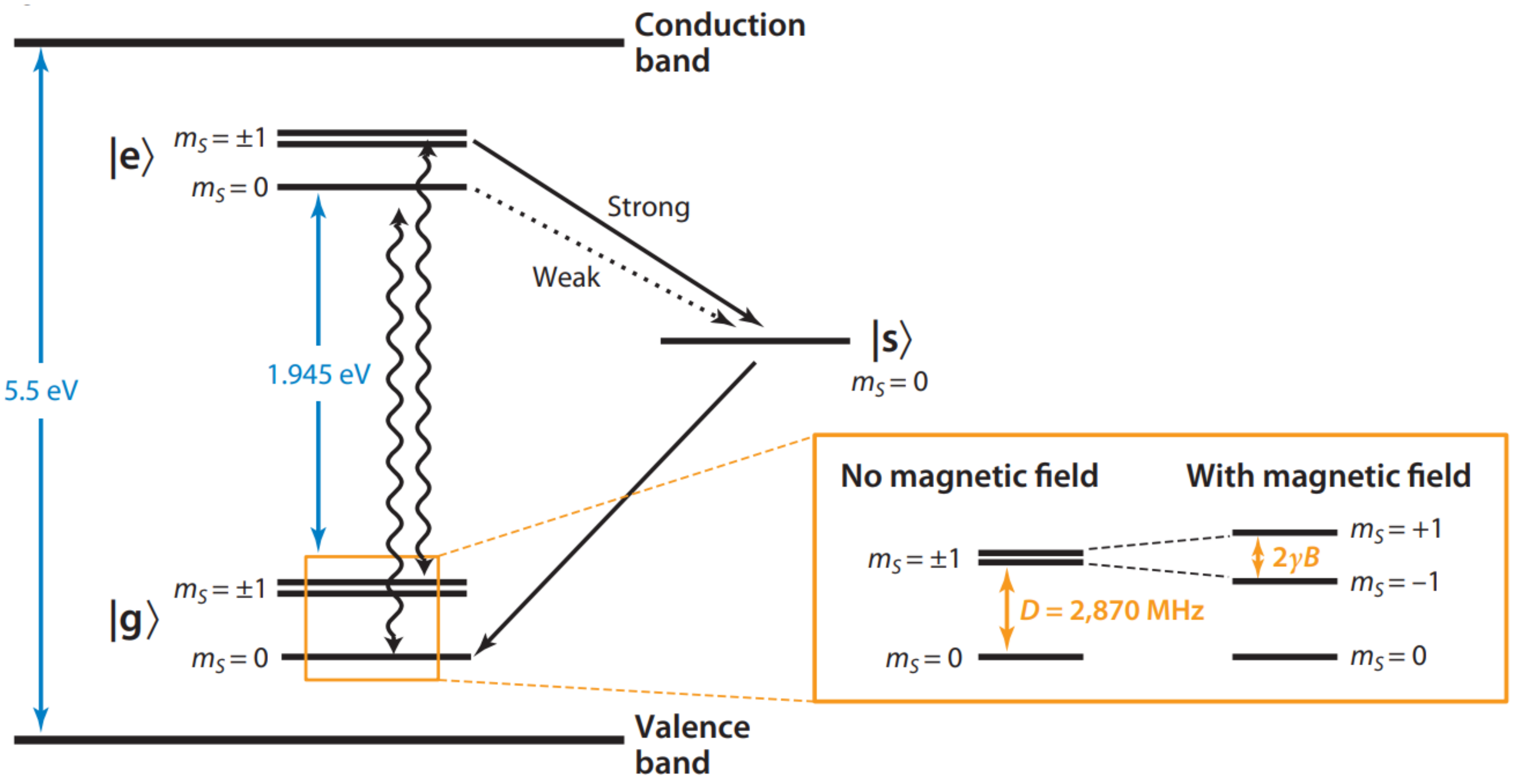
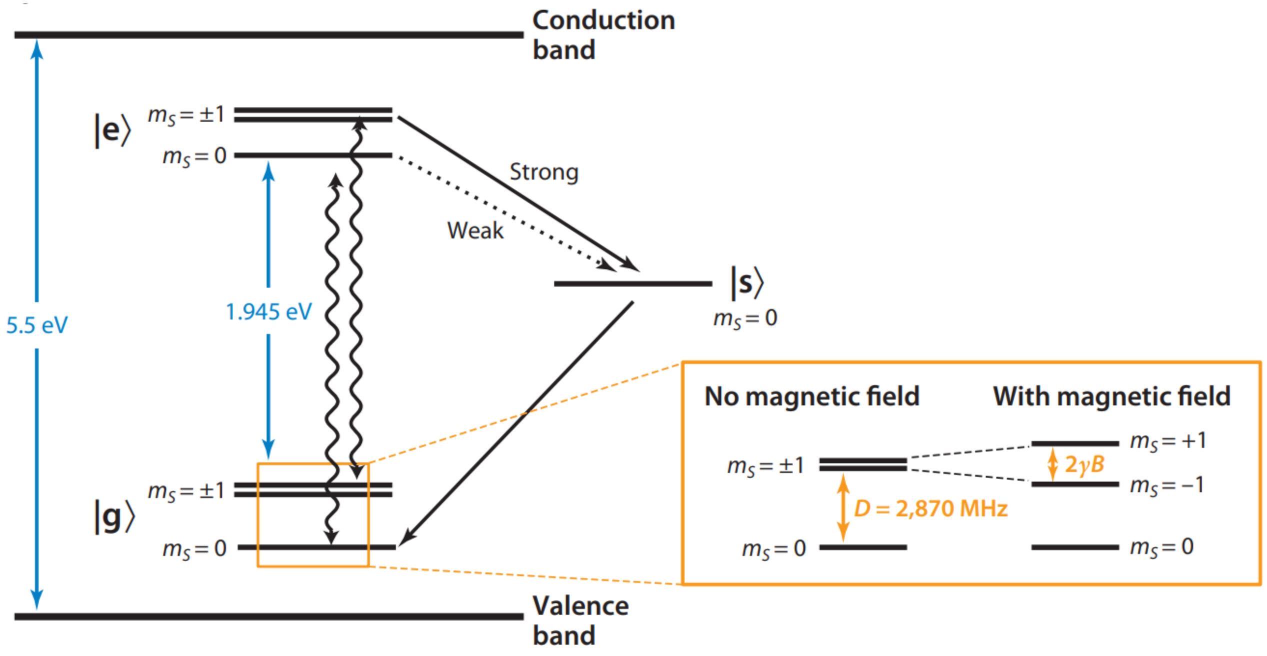
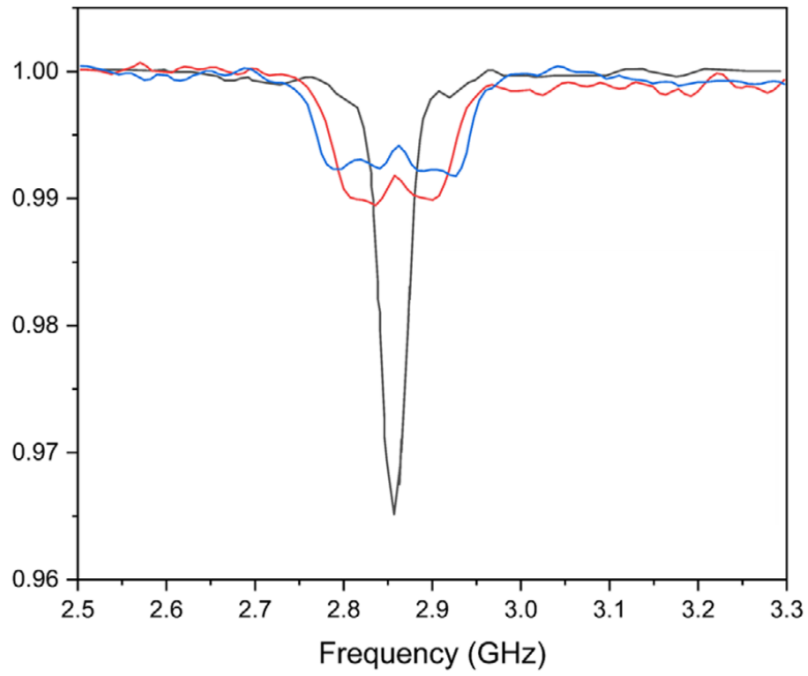
- NV center provides intra-band states
- Splitting between m_s = +/- 1 and m_s = 0 due to crystal lattice
- Wiggly lines represent photon absorption/emission
- Relaxation from m_s = +/- 1 state can take "dark" route
- External magnetic field induces Zeeman splitting of m_s = +/- 1 states



Optically-detected Magnetic Resonance

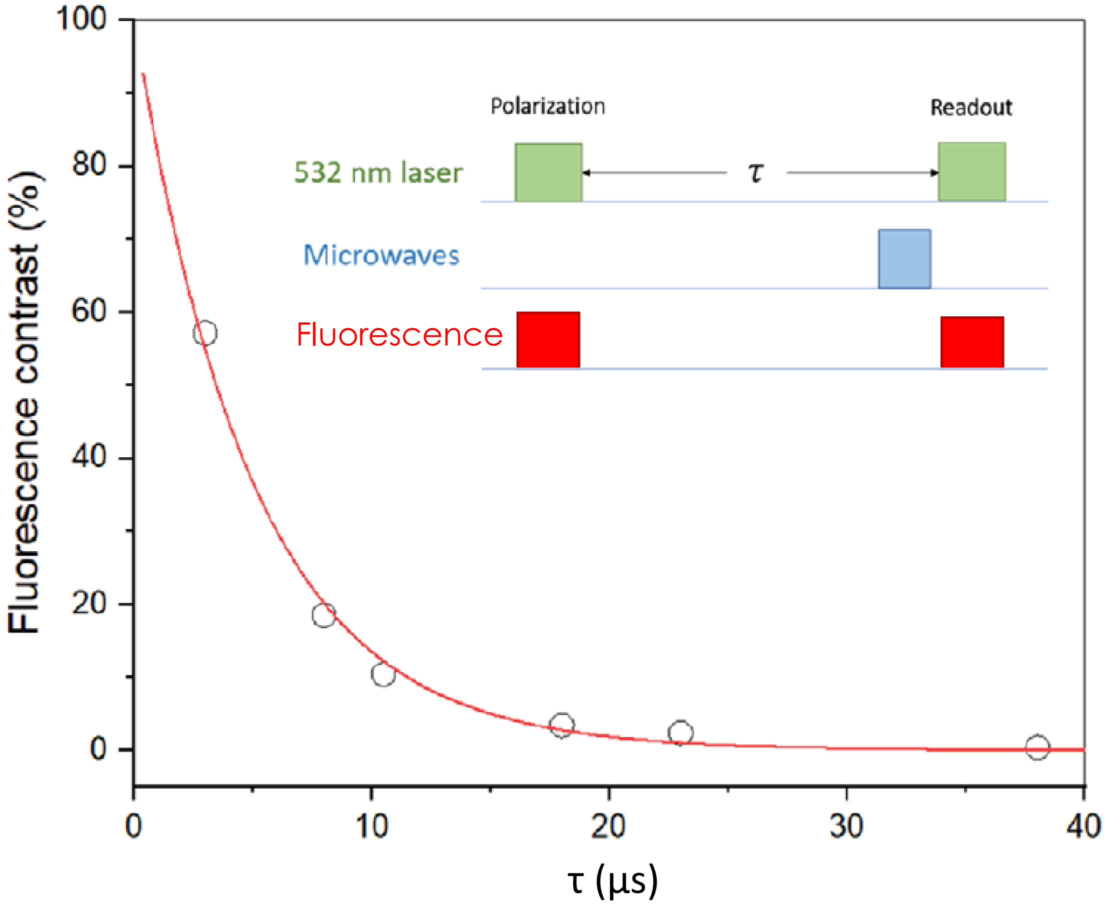
- Continuous wave optical and AC magnetic field excitation
- Electrons excited from m_s = +/- 1 have a chance to decay via "dark" route
- When AC B-field resonant with $m_s = 0 \rightarrow m_s$ = +/- 1 transition, quenching of fluorescence observed
- Application of external DC B-field induces Zeeman splitting, two resonances can be observed
- Resonance and splitting can be used to measure local B-field





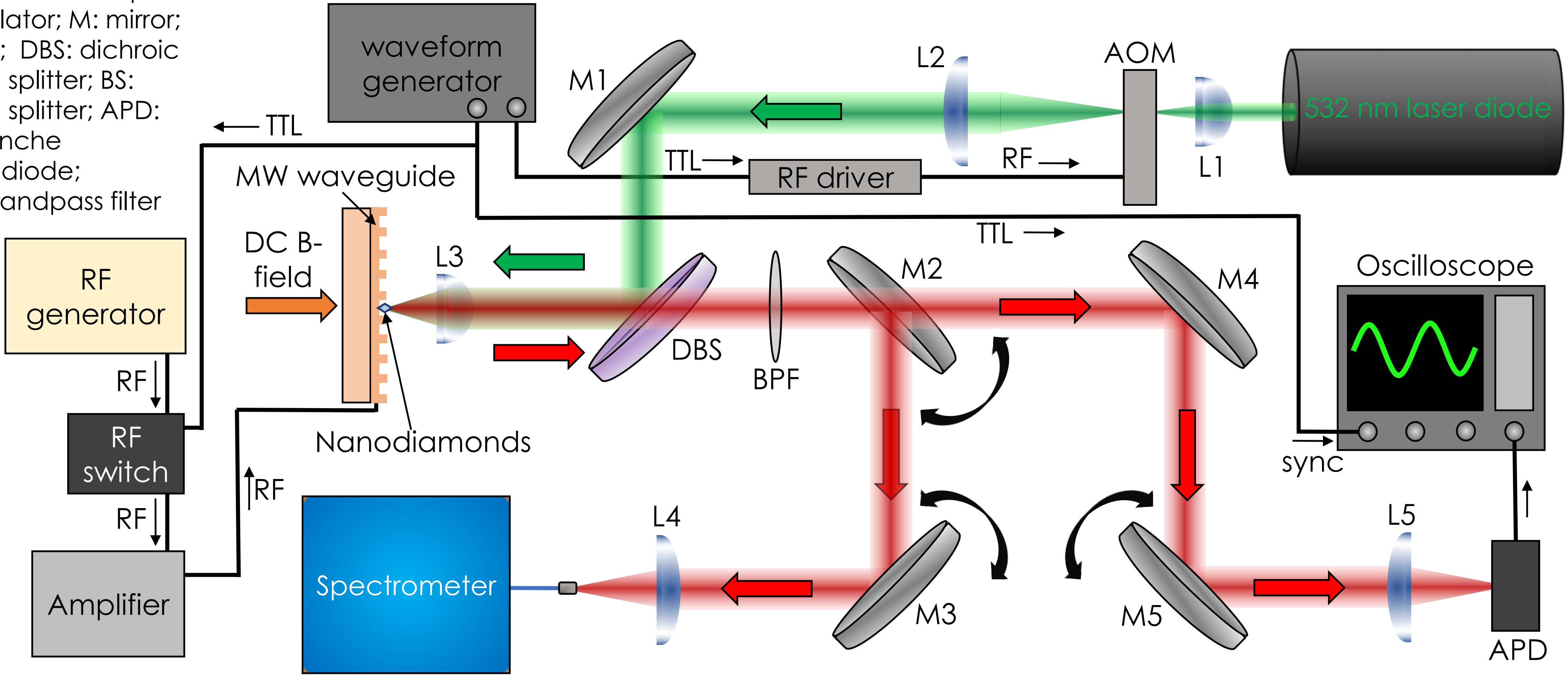
Spin Relaxometry

- Pump-probe-like excitation scheme
- Lone optical pulse acts as pump, polarizes spin
- MW pulse immediately followed by optical pulse acts as probe
- MW pulse modifies spin state, optical pulse probes spin state
- Measure contrast between fluorescence pulses from pump and probe
- Vary time between optical pulses, τ
- Fit contrast vs. τ with exponential, extracted rate is spin relaxation time



ODMR & Spin Relaxometry Schematic

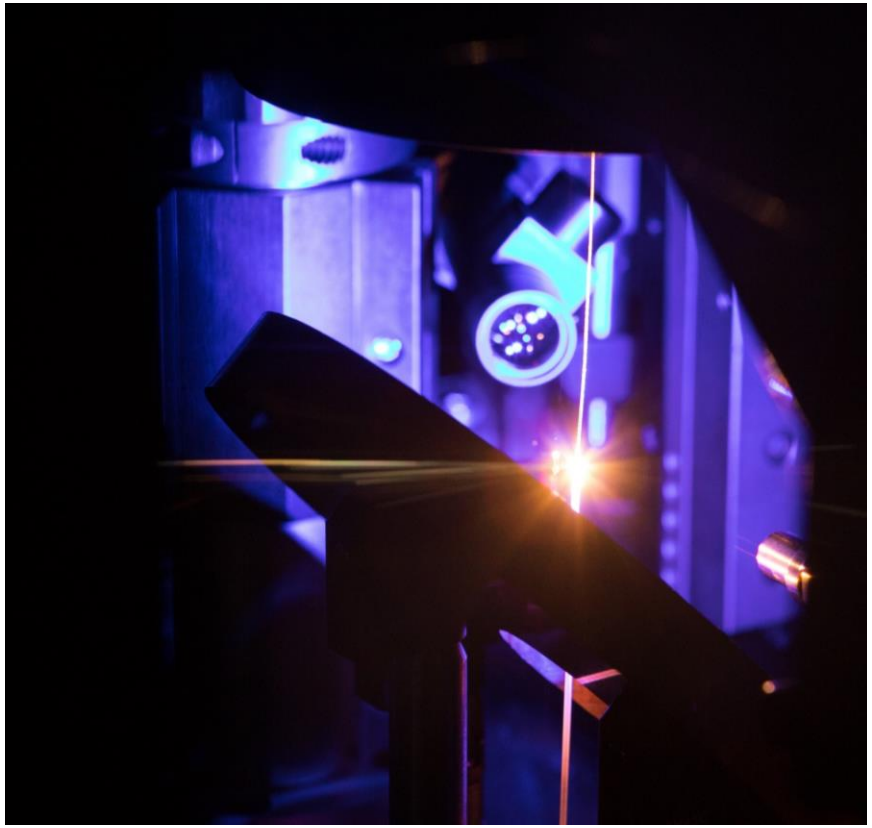
AOM: acousto-optic modulator; M: mirror; L: lens; DBS: dichroic beam splitter; BS: beam splitter; APD: avalanche photodiode; BPF: bandpass filter

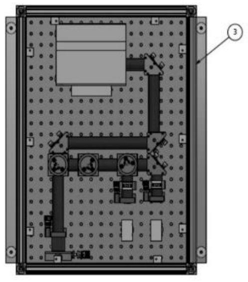


Laser-heated Pedestal Growth and Raman Distributed Temperature Sensing System

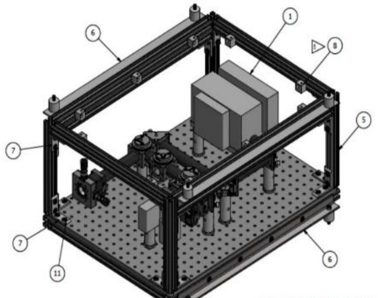
Motivation

- Optical fiber used in many sensing applications
- Silica fiber cannot withstand harsh environments, single-crystal (SC) fiber can
- SC fiber innately lacks cladding layer, which is necessary to act as efficient optical waveguide
- Developed method to grow SC fiber with cladding layer
- Can be used in Raman distributed temperature sensor (DTS) system in harsh environments

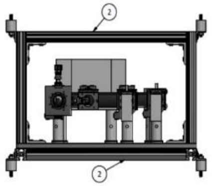




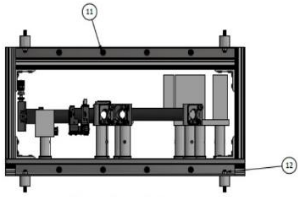
RAMAN DTS INTERIOR FRAME
TOP VIEW



RAMAN DTS INTERIOR FRAME
ISOMETRIC VIEW



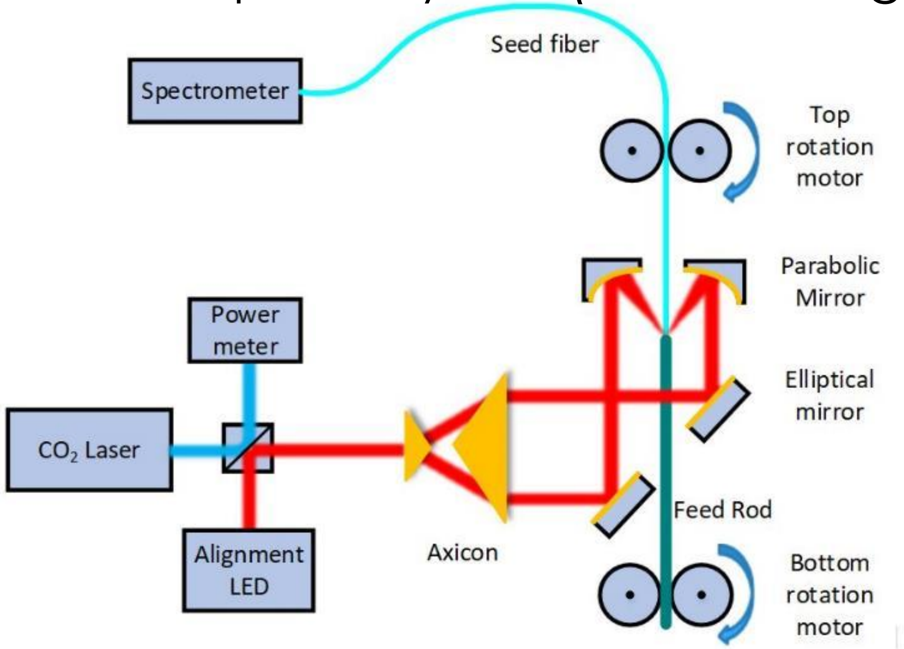
RAMAN DTS INTERIOR FRAME
FRONT VIEW

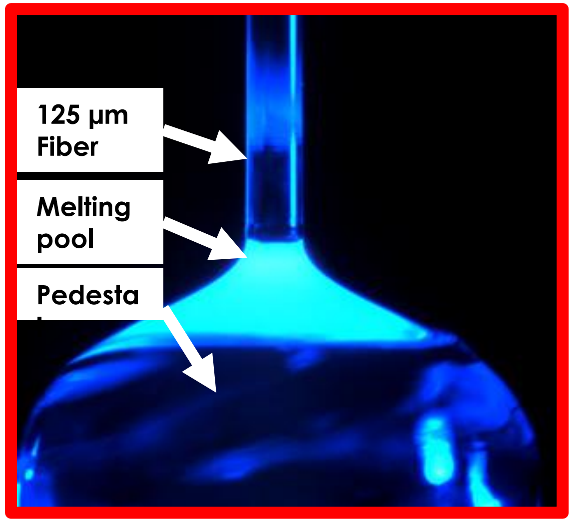


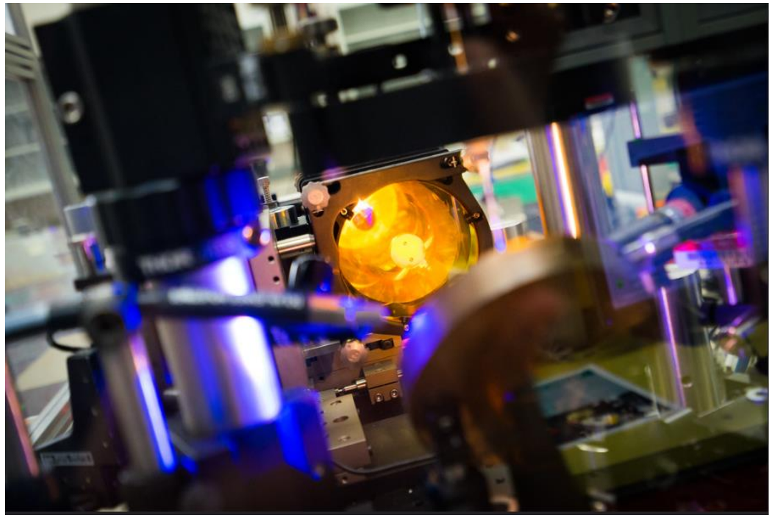
RAMAN DTS INTERIOR FRAME
SIDE VIEW

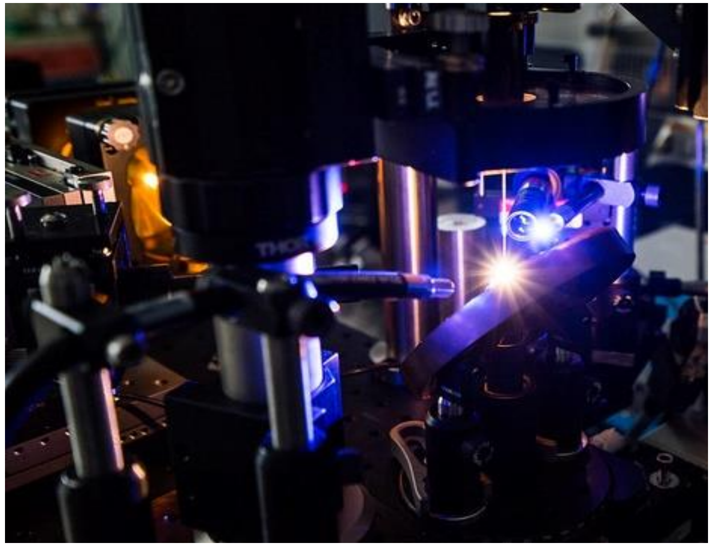
Laser-heated Pedestal Growth

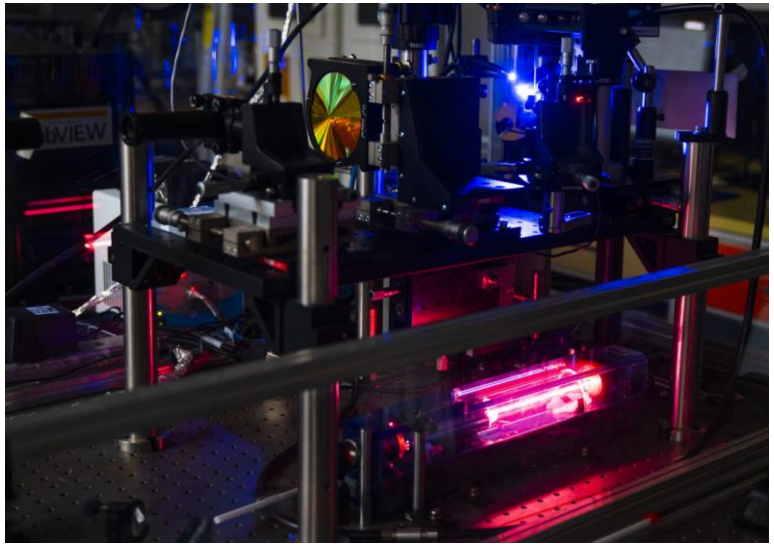
- CO_2 laser source for heating
- "Doughnut" beam shaper surrounds molten zone with light
- Motors advance feedstock (pedestal) and fiber
- Slow process (mm/min)
- Grows pure crystals (no cladding)





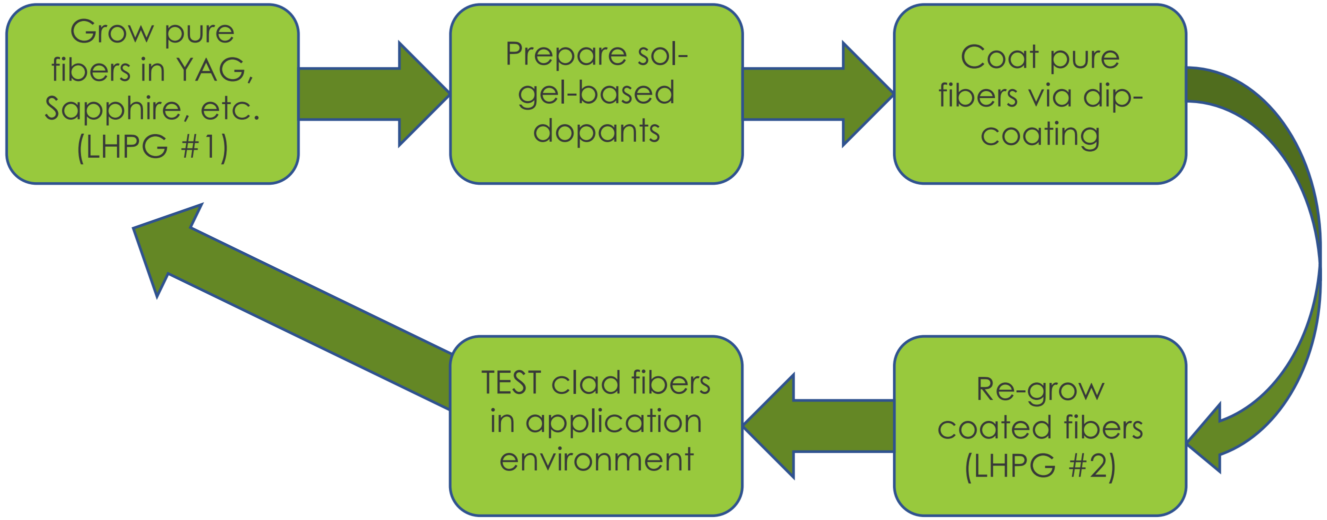


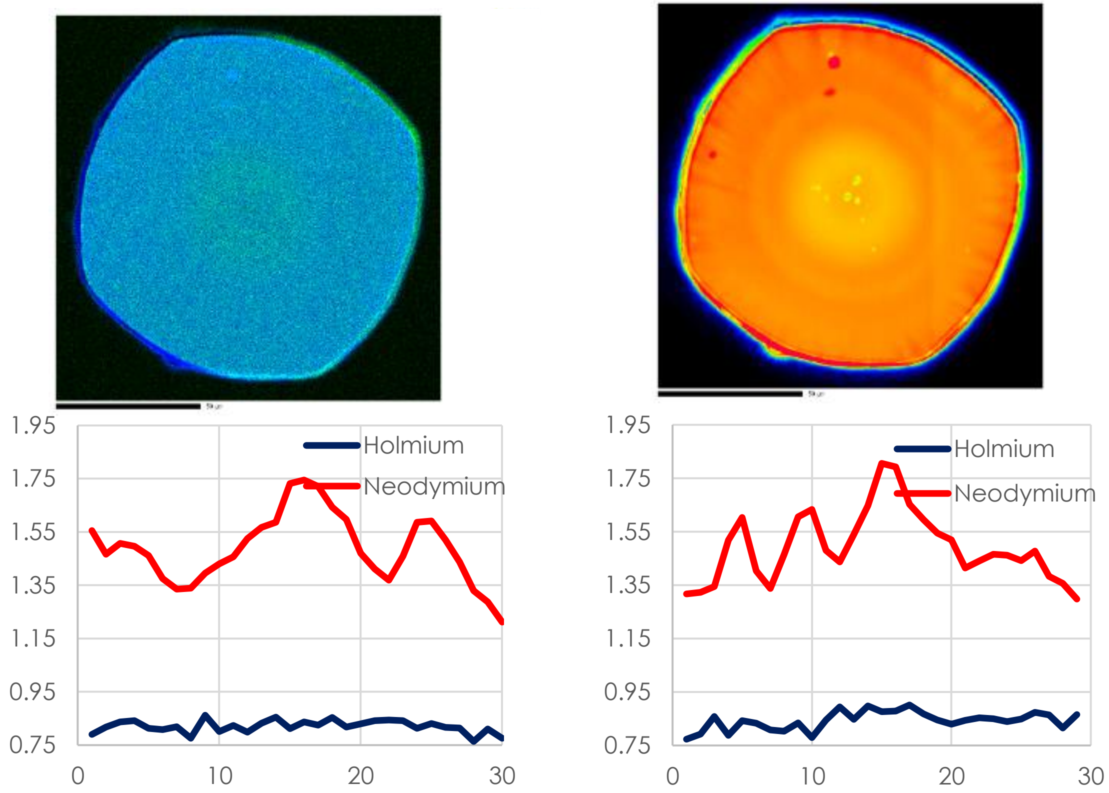




Dopant Additions via Regrowth of Sol-gel Coated Fiber

- Grow cladded fibers with two-stage LHPG
  - Sapphire or yttrium aluminum garnet (YAG)
  - Sol-gel (or other) dopant additions
- Evaluate materials' compatibility in energy systems
- Improve fiber performance

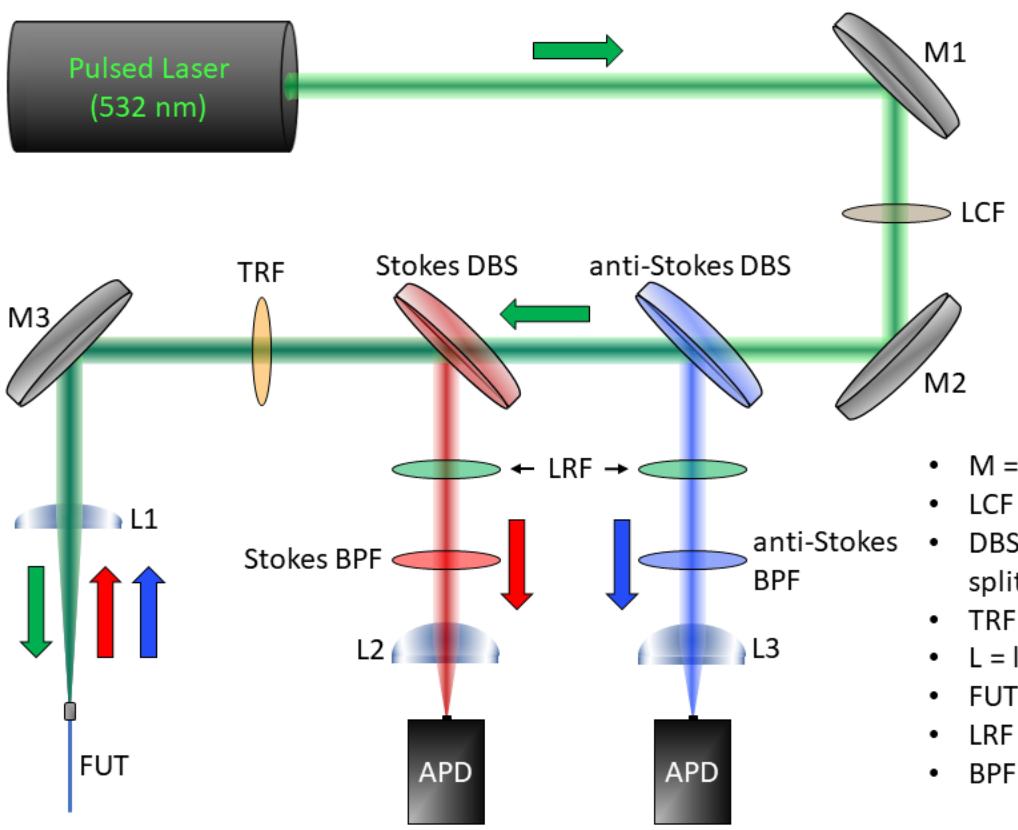




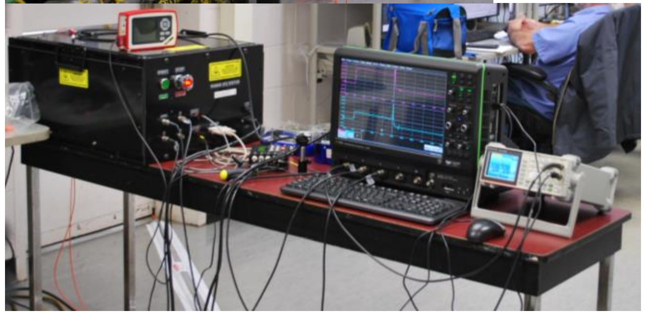
Automatic Dopant Segregation through LHPG: Top left: Visible light guiding in GRIN YAG fiber; Top right: EMPA map of Nd concentration in a GRIN YAG fiber; Bottom plots: Co-doped Nd and Ho: YAG fiber dopant concentrations in X (left) and Y (right)

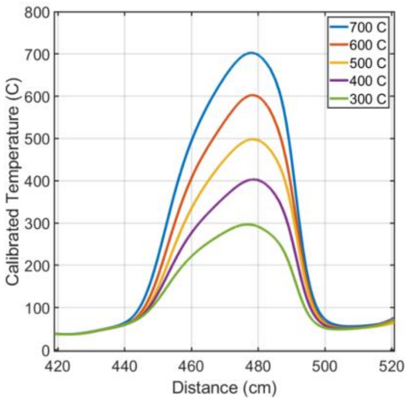
Raman DTS System

- Pulsed ~350 ps, 532 nm green laser
- Excites Raman scattering as pulse propagates
- Collects Raman with fast avalanche photodiodes
- Optics designed for sapphire or yttrium aluminum garnet (YAG) fiber
- First interrogator for single-crystal fiber



- M = mirror
- LCF = laser cleanup filter
- DBS = dichroic beam splitter
- TRF = thermal reject filter
- L = lens
- FUT = fiber under test
- LRF = laser reject filter
- BPF = bandpass filter





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