

Magnetic Field Vector Measurements Using Doppler-Free Saturation Spectroscopy

BETHE Kickoff Virtual Workshop
Aug. 11–12, 2020

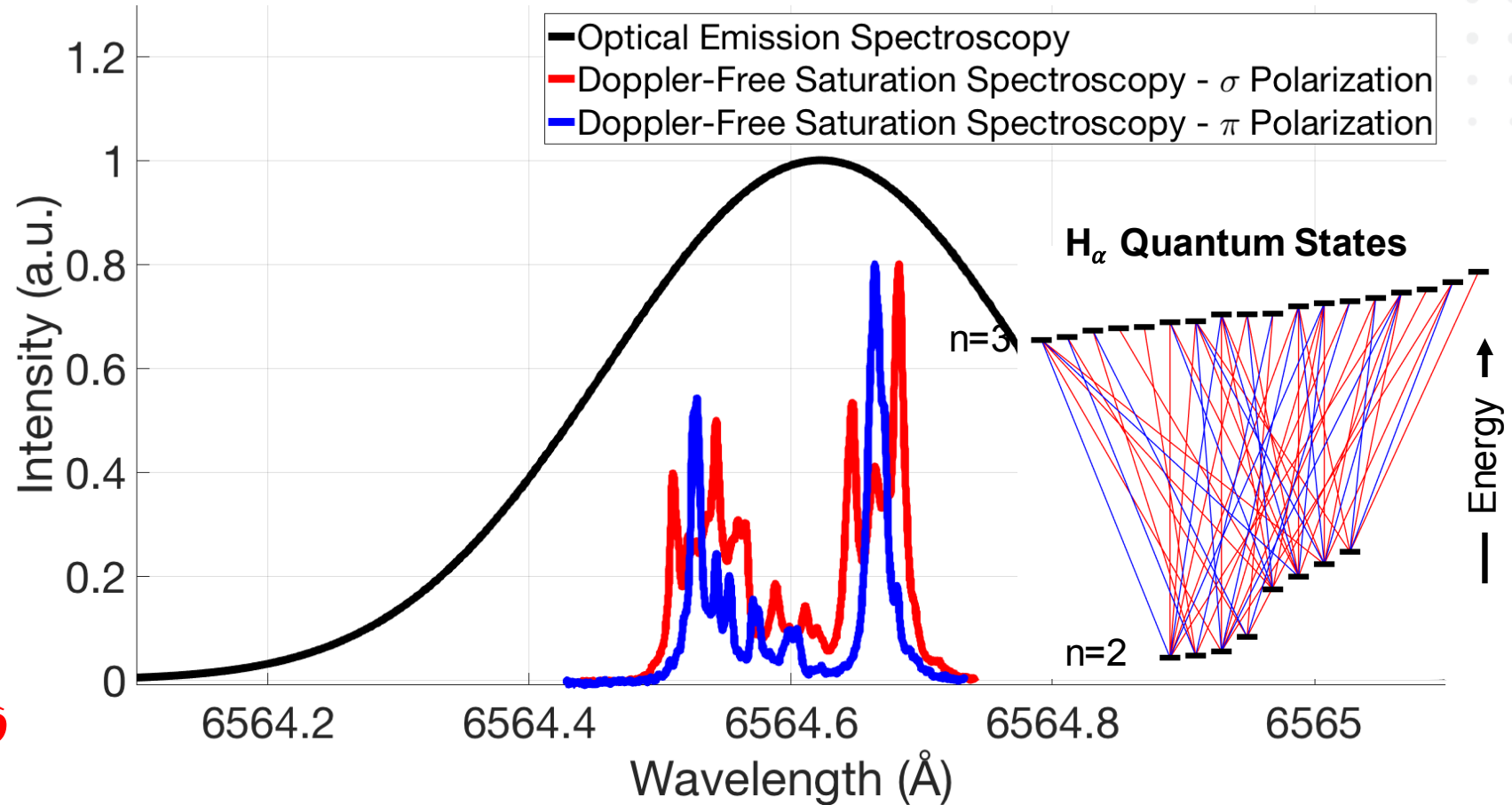
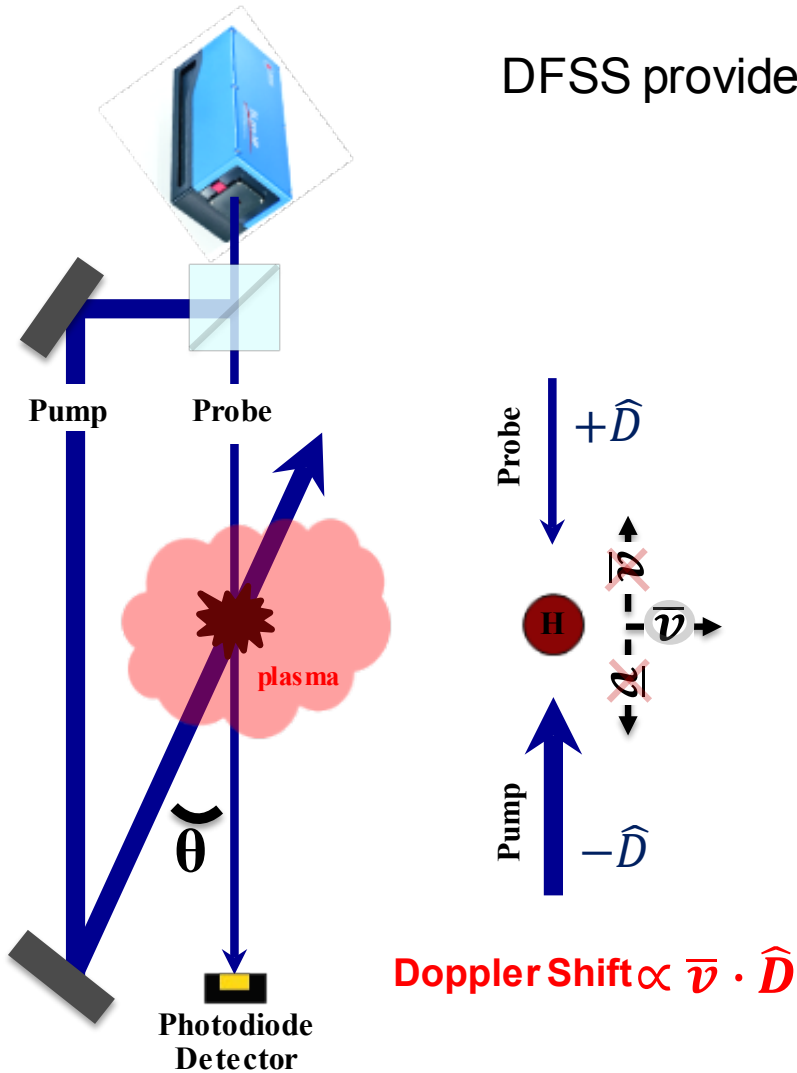
Elijah H. Martin, Oak Ridge National Laboratory

David C. Donovan, University of Tennessee - Knoxville



DFSS IS A LASER-BASED SPECTRAL LINE PROFILE MEASUREMENT

DFSS provides two key benefits: reduced Doppler broadening (up to x500) and localization.



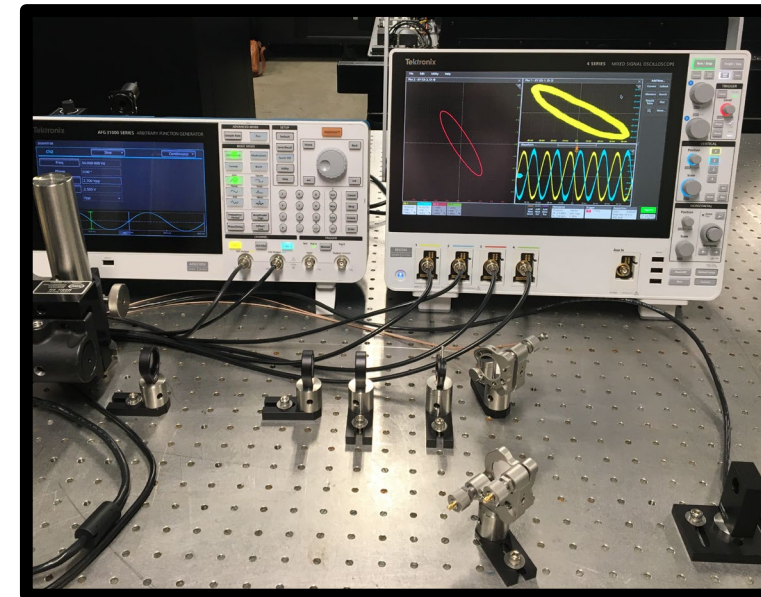
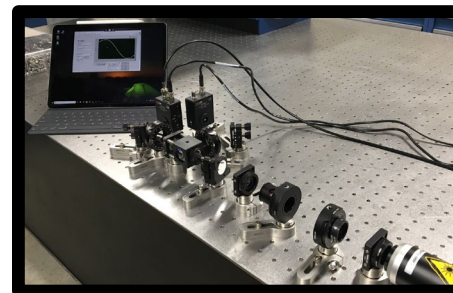
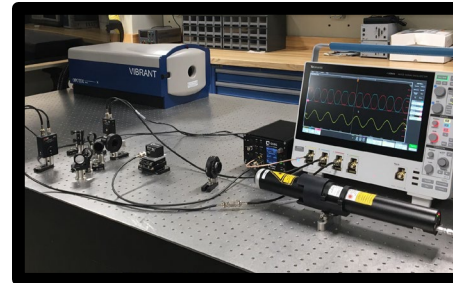
Team members and roles

▶ Elijah H. Martin

- Diagnostic design and assembly.
- Performance verification via laboratory demonstration.
- Identification of concept teams.

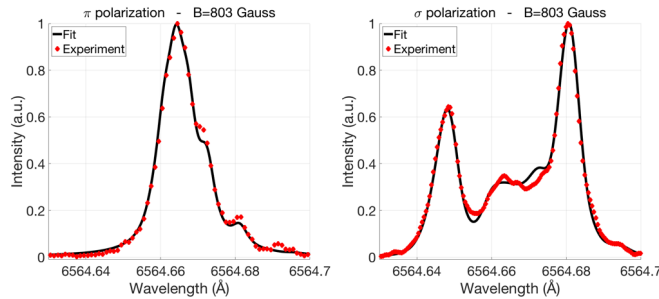
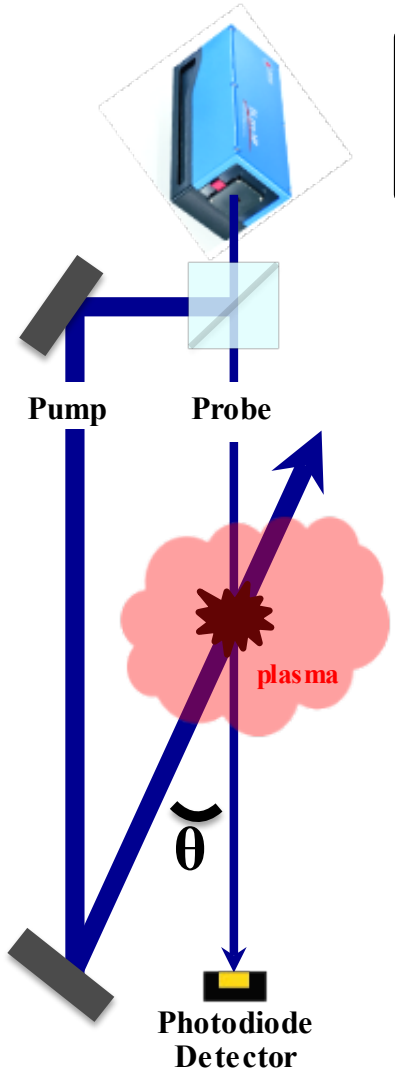
▶ David C. Donovan

- Subsystem performance verification.



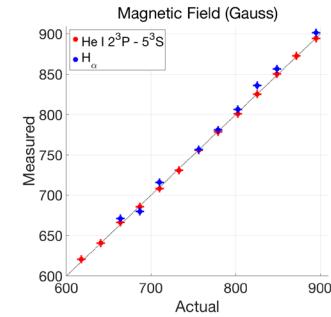
High-level motivation and goals of the project

Provide experimentally measured equilibrium B-field data needed to optimize and accelerate the fusion-concept.



$$i\hbar \frac{\partial \Psi}{\partial t} = \hat{H} \Psi$$

— FIT —>



Applicability

1. Atomic H/D neutrals ($\geq 10^{10} \text{ m}^{-3}$)
2. Optical access at two locations
3. B-Field ≥ 10 to 20 Gauss

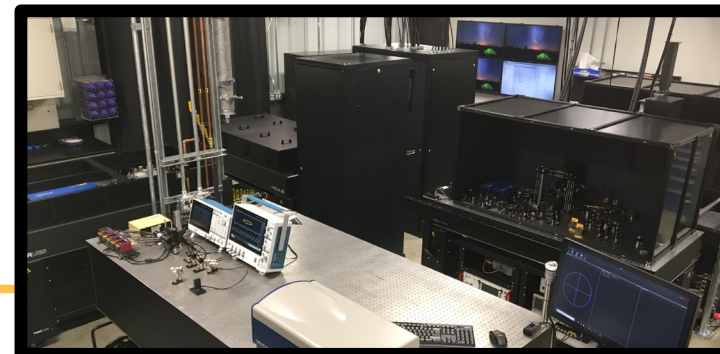
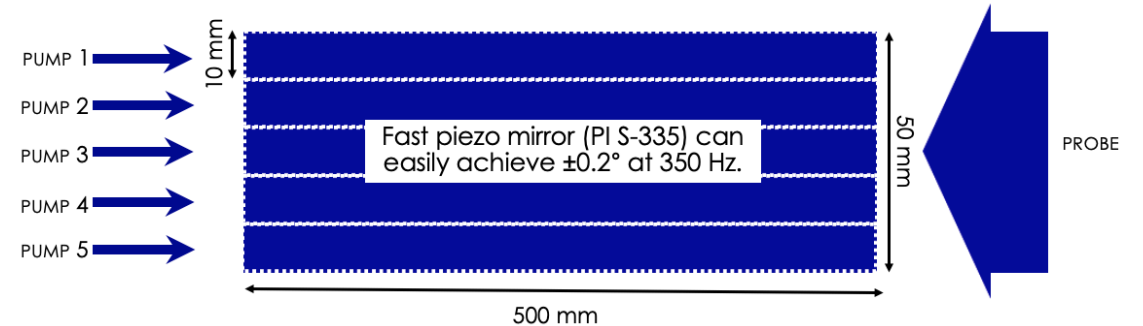
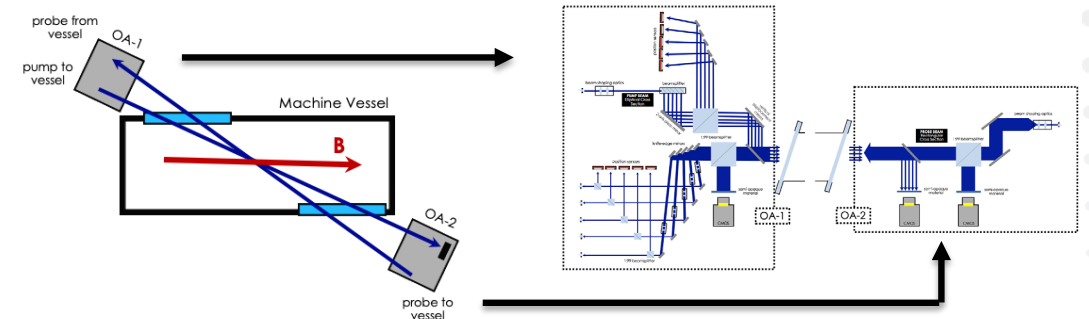
Capability

1. B_{\parallel} magnitude/polarity (± 5 Gauss)
2. B_{\perp} magnitude (± 5 Gauss)
3. mm (\perp) to cm (\parallel) resolution
4. 5 to 20 ms temporal resolution

Major tasks, milestones, and desired project outcomes

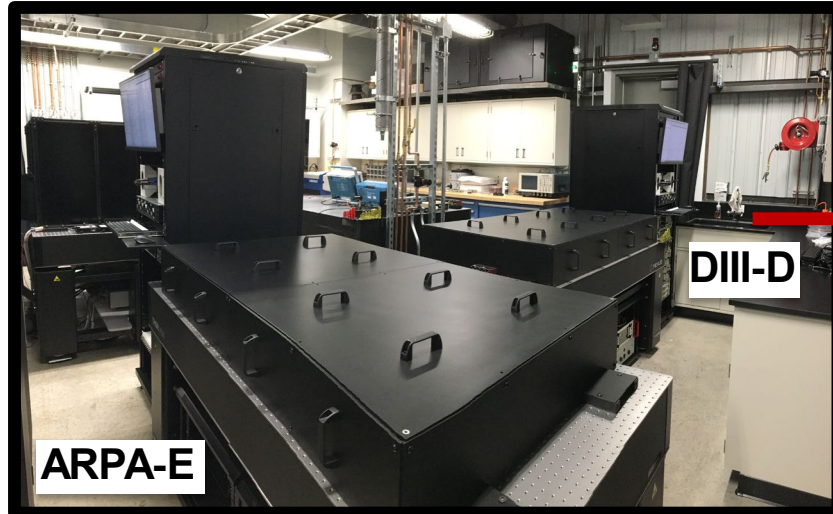
Major Tasks/Milestones

- ▶ DFSS diagnostic design (8-15-2020).
- ▶ Verification of laser steering and alignment capability (8-15-2020).
- ▶ Verify DFSS diagnostic's magnetic field measurement accuracy (2-15-2021).
- ▶ Verify ability to increase spectral signal-to-noise ratio (2-15-2021).
- ▶ **DFSS diagnostic commissioned (2-15-2021).**



Key techno-economic metrics of the project

- ▶ Provide deployable diagnostic for magnetic field vector measurements in <1 YR:
 - ± 5 Gauss accuracy and polarity for $B_{||}$
 - 50 x 500 mm measurement region with mm (\square) to cm ($||$) resolution
 - 5 to 20 ms temporal resolution
 - performance verified at ORNL

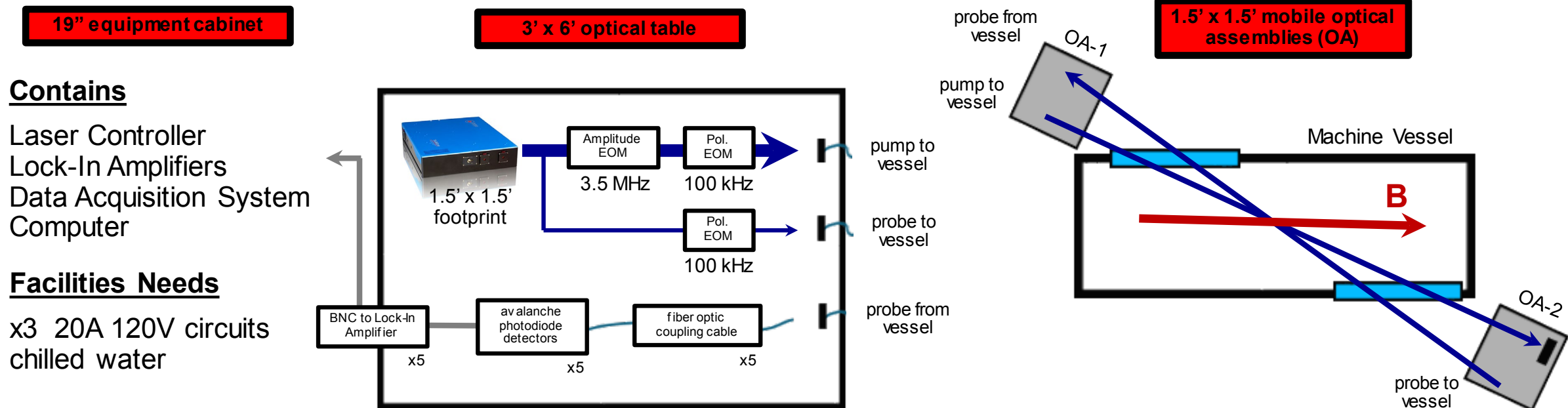




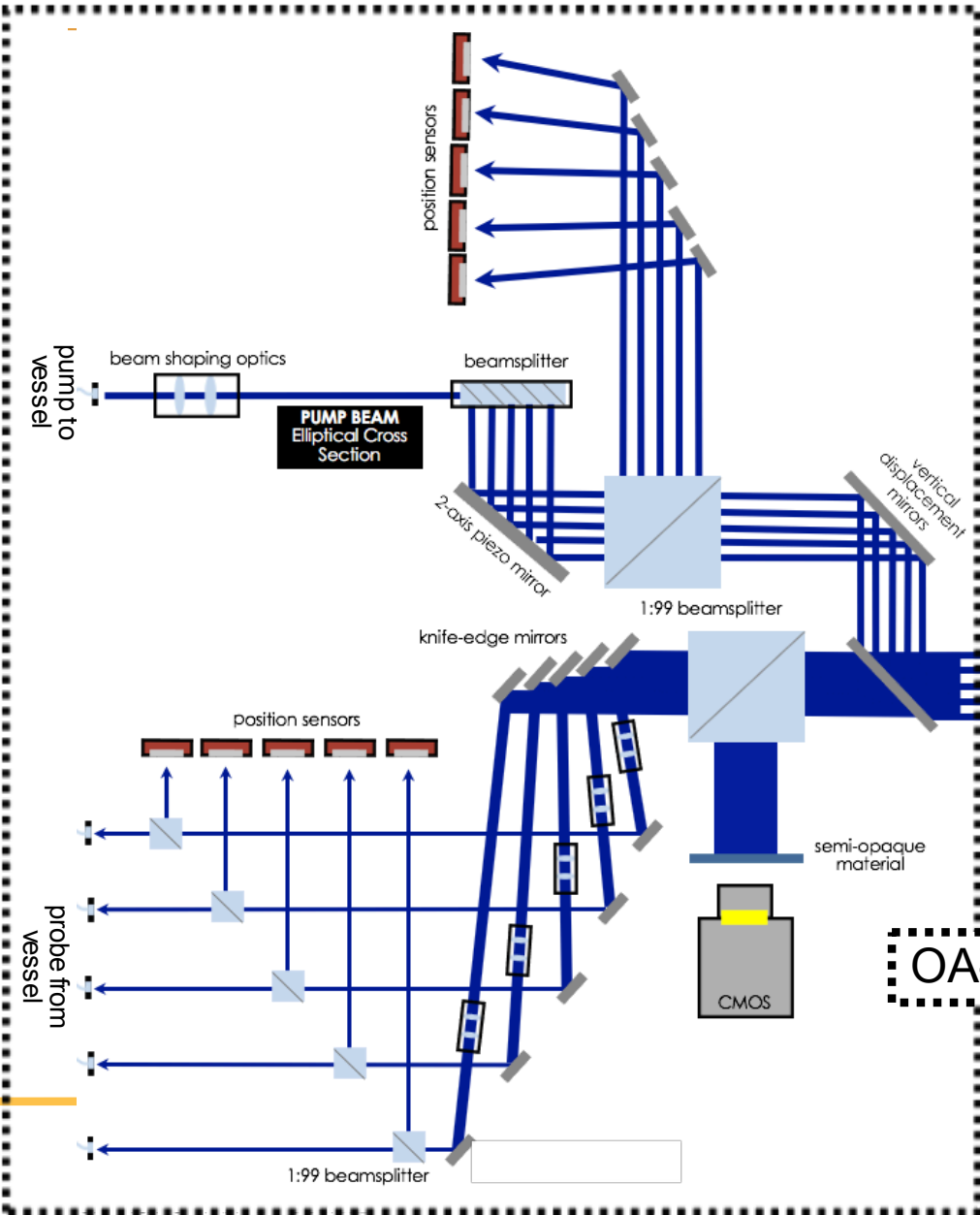
Questions?

The laser is connected to vessel via fiber

- Reduces diagnostic footprint near vessel and allows 'easy' sightline reconfiguration.
- Laser is a Toptica TA-SHG pro (1000 mW CW). Mode hop free tuning range of 20-30 GHz with 1 kHz maximum sweep rate.
- The laser source and DFSS hardware are contained within a 19" equipment rack and 3' x 6' optical table. Optical assemblies are used to shape, steer, and collect the beam.



OPTICAL ASSEMBLIES ARE COMPACT AND MOBILE



- Pump laser beam steering is achieved with a single piezo mirror. Position measured in real-time. Alignment monitored with camera.
- Probe laser beam alignment monitored with cameras.

