Fiber Laser Grand Challenge

LDRD
LABORATORY DIRECTED RESEARCH & DEVELOPMENT

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Problem

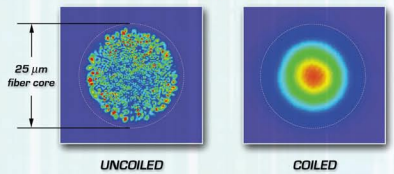
- Many applications of high-power lasers have been rendered impractical by current technology
  - Conventional laser systems are bulky, fragile, inefficient, and/or provide poor beam quality
  - Applications span all Sandia SMUs

Vision: *A new generation of compact, efficient, versatile, and highly integrated laser systems*

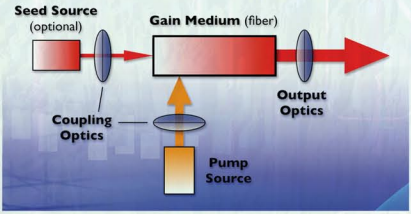
Approach

- Based on Sandia breakthrough in power scaling of fiber lasers
  - "Bend-loss-induced mode filtering"
  - Large-core fiber is coiled to introduce preferential loss for high-order modes
  - Provides diffraction-limited beam quality with little loss in efficiency
  - Patented and licensed - *de facto*, worldwide standard for power scaling

Measured output beam profiles



- Sandia is taking a comprehensive approach, addressing all aspects of the laser system
  - Fiber design - high power, embedded functionality
  - Development of microlaser seed sources
  - Embedded-mirror side pumping - including direct diode-bar pumping
  - Pump diode development
  - Fiber end preparation - increased damage threshold, output beam formatting
  - Laser/amplifier fabrication
  - Measurements of fundamental materials properties - optical damage thresholds, nonlinear coefficients, photo-darkening radiation damage, purity, composition and index profiles
  - Waveguide and laser/amplifier modeling - including nonlinear processes
  - System engineering and testing

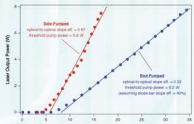


Goals

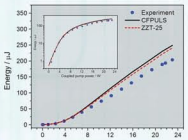
- Scale peak power of fiber lasers to the multi-MW level
  - Reach ultimate physical limit of the technology
- Integrate nearly all components into monolithic fiber-optic platform
  - Ruggedness and reliability
  - New device designs and system architectures

Key Results

- **>100x power scaling** beyond "single-mode limit"
- **1.3 MW** peak power and **1.1 mJ** pulse energy with diffraction-limited beam quality ($M^2 < 1.2$)
- Peak in-fiber irradiance of **440 GW/cm²** (world record)
- Direct diode-bar pumping of fiber array with **84% coupling efficiency** (conventional approach provides only ~50% eff.)
- Generation of wavelengths from **213 to 4400 nm**
- Development of **high-fidelity models** to treat amplification in coiled fibers

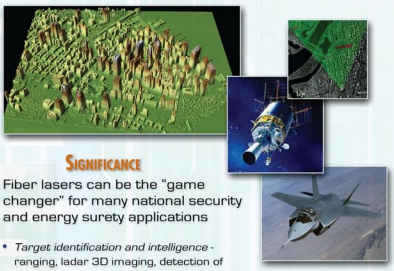


Diode-Bar Side Pumping Provides 2x the Efficiency of the Conventional Approach



Comparison of Theory and Experiment

Packaged fiber amplifier



Significance

Fiber lasers can be the "game changer" for many national security and energy surety applications

- *Target identification and intelligence* - ranging, ladar 3D imaging, detection of concealed targets
- *Homeland security and defense* - standoff chem/bio plume detection, real-time point sensors, explosives detection
- *Directed energy* - missile defense, IR countermeasures
- *Laser designators*
- *Non-lethal weapons*
- *Pollution detection and prevention* - power plants, refineries, pipelines

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