Researchers simulate self-focusing beams in high-power fiber lasers

Sandia research significantly impacts power scaling of fiber lasers

In remote sensing systems, data are often sent via laser light over optical fibers. A unique class of fibers is also used to generate the laser light within the fiber. Increases in the attainable peak power of these rare-earth-doped "fiber lasers" to the megawatt (MW) level have enabled these sources to replace conventional lasers in a variety of applications. However, too much power causes self-focusing (SF), a nonlinear process in which the radial variation in beam intensity causes a corresponding variation in the instantaneous refractive index (RI) in the fiber (see figure). The resultant lens-like RI profile causes the propagating beam to contract. If the power exceeds a certain critical value (P_{crit}), catastrophic SF will occur, causing dielectric breakdown that destroys the fiber.

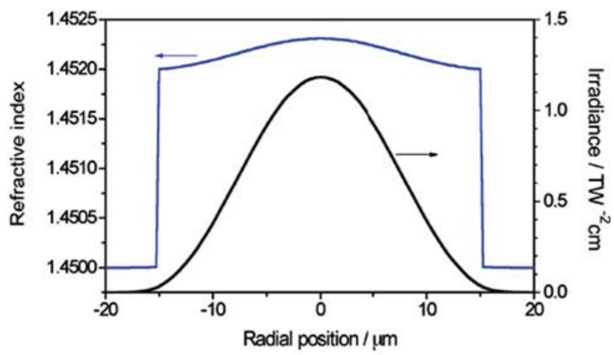
Although SF in bulk media has been well studied, significant confusion exists in the literature concerning SF in optical fibers, and no work has addressed SF in fiber lasers. As such, further power scaling requires an understanding of SF beams in fibers.

Sandia researchers, supported by the Fiber Laser Grand Challenge LDRD program, have addressed the key, fundamental issues associated with SF in fiber lasers via detailed numerical simulations. Their analysis showed the following:

- At all powers below P_{crit}, stationary (non-oscillatory) modes exist that propagate unchanged in the fiber (in contrast to literature reports).
- In a fiber amplifier, the propagating beam will adiabatically evolve through a series of stationary modes.
- The value of P_{crit} is nearly identical in a fiber and in a similar bulk medium.
- These conclusions hold for both straight and coiled fibers.

This work has significant implications for power scaling of fiber lasers. For example, although coiling of the fiber changes the waveguiding properties of the fiber and substantially distorts the fiber modes, this effect will not lower P_{crit}. Similarly, the previously reported oscillatory behavior lowers the effective threshold for parasitic nonlinear processes and optical damage, but real-world fiber lasers will not be subject to this limitation.

In the future, the Sandia codes will be used to analyze the SF behavior of more complex fiber designs, with the goal of exploiting the unique properties of waveguides to increase the attainable power from compact, practical laser systems.



Fundamental-mode irradiance profile (black) and resultant RI profile (blue) for a step-index fiber with a 3 MW beam. The bulge at the center of the RI profile results from the nonlinear response of the RI to the irradiance (Kerr effect), acting as a lens that causes SF.

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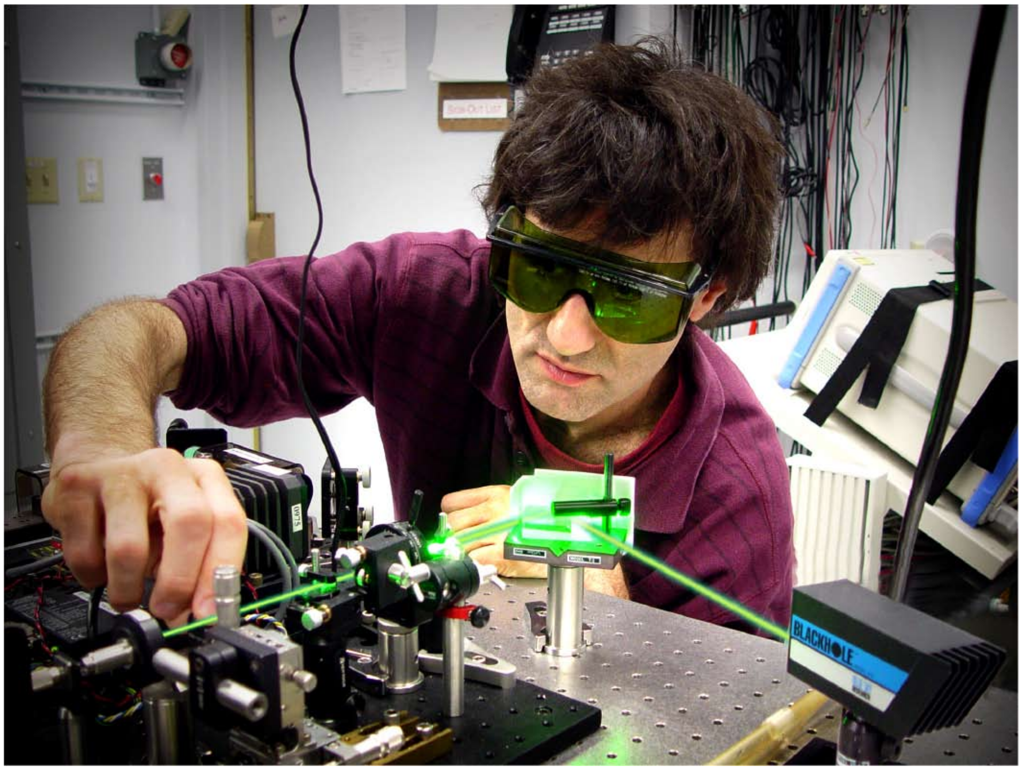

Sandia researcher, Dahv Kliner, works on a bend-loss-induced mode filtering method that allows the use of large core diameter fibers while maintaining high beam quality.

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