The Potential of Fibre Lasers

David N Payne

Optoelectronics Research Centre, University of Southampton, UK
SPI Lasers plc

Born out of the optical telecoms revolution, the high power fiber laser challenges currently held views on how to make, repair, and destroy things. With small size, maintenance-free operation, high thermal and electrical efficiency and outstanding (diffraction- limited) beam quality, it has the potential to change every industry and discipline it encounters. Unique among high power lasers, the fiber laser is monolithic, the light being entirely confined to the fiber core. This gives immunity to thermal distortion of the beam, almost instant startup, very high stability and protection from the environment. Maintenance is minimal, since no realignment or cleaning of components is necessary.

One of the key attributes of fiber lasers is their very high gain (30dB) which results from their extended length. This allows the use of amplifiers as the preferred configuration, rather than oscillators, as used in most conventional lasers, giving far greater design freedom. As an indication of the extraordinary range of performance available from fiber lasers in c.w., pulse or single frequency regimes, the following results have been obtained recently in our laboratories:

CW laser Configuration
- 1.36 kW Yb-doped fibre laser (M^2=1.4)
- 633 W PM Yb-doped fibre laser
- 188 W 1550 nm Er/Yb co-doped fibre laser ("eye safe")
- 75 W 2 μm Yb-sensitized Tm-doped fibre laser

Master Oscillator/Power Amp Configuration (MOPA)
- 402 W / 511 (PM / Non-PM) single-frequency Yb-doped fibre MOPA
- 151 W 1562 nm single-frequency Er/Yb co-doped fibre MOPA

Pulsed
- 120 W Q-switched Yb-doped fibre laser (0.6/8.4 mJ/pulse)
- 60 W 4 ps 10 GHz Er/Yb codoped fibre MOPA (1550 nm)
- 321 W 20 ps 1 GHz Yb-doped fibre MOPA (1060 nm)

Records are tumbling at every conference, leading to the question of what are the limits. Noteworthy are the results for single frequency (~20kHz linewidth), polarized laser output in a master oscillator/power amplifier (MOPA) configuration. Multiple amplifiers fed from a single seed source can be coherently beam combined provided they are polarized and narrow-linewidth. This provides a means of scaling fiber lasers from the current diffraction-limited record of 2.5kW reported by IPG to perhaps beyond 100kW by stacking kW fiber lasers in beam-combined arrays with near-perfect beam quality.

The MOPA configuration offers further advantages for pulsed lasers. Under the operator's control and using a low-power diode laser seed, the output pulse from a multi-stage pulsed MOPA laser can be carefully shaped to optimize peak power and processing parameters. In fact, there is little need to use the traditional and often fragile Q-switching or mode-locking techniques, when better control can be obtained through amplification to the kW regime. This revolutionary concept has led, for example to a recent report of a 321W Er:Yb MOPA operating at 1550nm and giving 20ps pulses at 1GHz. At a commercial level, lasers giving ~10mJ, 100ns pulse width at 10kHz prf are available.

Despite these impressive results, fibre laser development is still in its infancy. We can expect perhaps 10kW output from a single diffraction-limited fibre, with several combining options for power-scaling to 100's of kW. Numerous pulse schemes are also available, giving pulses from 10's of fs to 20's of ns. Pulse energies up to 100mJ can be obtained from large core designs. Finally, wavelengths from 800nm to 2.1μ and beyond are seamlessly available through appropriate choice of rare-earth dopant or through Raman shifting.