Challenges in Power Scaling of Pulsed Fiber Lasers

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Abstract: We discuss the key challenges in the power scaling of pulsed fiber lasers including nonlinear effects, self-pulsing, and optical mode management, and demonstrate >5 kW peak power levels from an all-fiber master oscillator power amplifier (MOPA) configuration.

Keywords: High power fiber lasers, Master Oscillator Power Amplifier, self-pulsing, nonlinear effects.

High peak power (kW level) pulsed lasers (tens of ns pulses at kHz repetition rate) find wide applications in material processing, medical surgery and defense. Fiber lasers are attractive for such applications as they provide advantages in terms of output beam quality, thermal management and efficiency over conventional solid state lasers. One of the widely used techniques to generate such high power laser pulses is the Master Oscillator Power Amplifier (MOPA) configuration (shown in Fig. 1), where stable low power laser pulses are generated using commercially available semiconductor laser and then amplified using an Ytterbium doped double-clad fiber [1].

![Figure 1: Schematic diagram of MOPA configuration.](image1)

However, to achieve stable pulses with kW peak power levels there are significant challenges to be overcome including amplified spontaneous emission (ASE), nonlinear effects, self-pulsing and gain saturation. In this paper we discuss each of this issues and possible solution to overcome it.

One of the fundamental limitations in power scaling of fiber lasers is the onset of nonlinear effects at high power levels. Conventional Yb doped double clad fiber with core/ cladding diameter of 5/125 μm can support only up to a few hundred Watts of peak power, which corresponds to the stimulated Raman scattering (SRS) threshold. In order to increase the nonlinear optical threshold, the core area and length of the fiber may be increased in specially designed fibers such as large mode area (LMA) double clad fiber [1]. The LMA fiber with a core/clad diameter of 25/250 μm has SRS threshold of 10 kW for about 10 m length. So, a dual stage amplifier design is necessary to scale to kW power levels. Care must also be taken to frustrate higher order modes and mode shifting in LMA fibers.

Another key challenge is the build-up of amplified spontaneous emission (ASE) in the backward direction. The ASE generation becomes more prominent in case of pulse amplification with low repetition rate (low duty cycle), and it also reduces the level of inversion available for the signal. Moreover, the ASE depleted the inversion at the input end of the fiber thereby creating a non-uniform inversion profile along the fiber. This has been observed to contribute towards self-pulsing as shown in Fig. 2.

![Figure 2: Amplifier output pulse train of MOPA along with a self-generated pulses](image2)

We have performed FDTD simulations to design the MOPA such that the above challenges may be overcome, resulting in the demonstration of >5 kW peak power in 40 ns pulses at 25 kHz repetition rate.

![Figure 3: Pulse at the output of second stage amplifier](image3)

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