Reverse-wave suppression in ring-resonator lasers

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Efficient transform-limited 1.6 μm pulsed Er:YAG lasers are useful for coherent Doppler LiDAR sensing of wind-fields due to the low absorption by water vapour and CO_2. Additionally, these wavelengths are within the eyesafe band and thus these systems can safely transmit the highest peak and average powers. Ring-resonator architectures are widely used to when using injection seeding to produce single frequency, transform-limited laser pulses, as they eliminate spatial-hole-burning effects reducing the likelihood of multi-mode lasing [2, 1]. They also offer the highest isolation for the master laser from light from the slave resonator.

Ring resonators exhibit bi-directional lasing under normal conditions, reducing the efficiency of the output. Several methods have been used to force ring lasers to operate in a uni-directional mode, including intracavity Farraday rotators, injection seeding, and external reverse-wave suppressor mirrors.

We developed a ring resonator with two 0.5 at. % Er:YAG crystals, each pumped by a 30 W, 1470 nm fibre-coupled laser diode. The laser is injection-seeded via a 2 mW master laser, resulting in 1 mJ, 240 ns pulses at 4 kHz. Injection-seeding our laser showed both the forward- and reverse-waves were equally seeded by the master laser. Zhang et al. theorise that the success of reverse wave suppression by injection seeding is dependent on the power, and that > 100 mW of seed power is required for successful seeding of a 4.2 mJ, 418 ns laser at 2 kHz [3]. However, Chen et al. successfully obtained uni-directional lasing using 15 mW of seed power in a ring resonator, resulting in a 2 mJ, 130 ns pulsed laser at 2 kHz [4].

We have developed a numerical model to further study this phenomena and have shown that effective reverse wave suppression is critically dependent on the coupling between the two directions. Coupling of < 0.1 % between the two directions results in near-equal magnitude of the forward- and reverse-wave pulses. We shall discuss these predictions and the impact on future developments of transform-limited, pulsed Er:YAG lasers.

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