Joint spatial profile and frequency conversion of an LP_{07}-fiber mode towards the blue spectral region

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The vast number of light detection and ranging (LIDAR) technologies has led to great advances in both scientific and industrial land-based and airborne applications [1,2]. However, the difficulties in generating high energy pulse in the 440-490 nm region, i.e. the water transmission window [3], has prevented realizations of naval LIDAR systems. Frequency conversion schemes of Yb-fiber [4] and Tm-fiber [5] systems have been proposed to address this issue. They do however respectively suffer from broad output spectra and the need for two free space second harmonic generation (SHG) stages, which could limit the conversion efficiencies.

Our approach instead relies on the power scalability of narrowband four-wave mixing (FWM) in higher order mode fibers to convert well-established commercially available 1064 nm Nd- and Yb-systems to the 970 nm region [6]. The output is then used for SHG in a periodically poled KTP-crystal to reach the water window. Transformation to a Gaussian-like beam profile is simultaneously achieved during the conversion process, which has previously been demonstrated for Gauss-Bessel beams [7], by controlling the phase mismatch [8].

The experimental system revolved around a 650 ps Q-switched Nd:YAG laser at 1064 nm, which was amplified in a double cladding Yb-fiber amplifier, and a tunable Ti:Sa laser at 972 nm to seed the FWM. Both lasers were converted to the LP_{07}-mode, to enable phase-matching, before launched into the multimode fiber. This resulted in a peak power of 5.6 kW at 972 nm, which was focused into a KTP crystal with a poling period of 6.66 µm. Fine-tuning the focusing conditions allowed us to generate remarkably clean on-axis conversion, as shown in Fig. 1 a). The conversion efficiency was however only about 10%, which resulted from that the crystal was placed 2 cm after the focal plane –thus limiting the intensity. SHG closer to the focal plane naturally improved the conversion efficiency, but also led to persistent ring structure.

A numerical investigation of the SHG for the experimental conditions was then undertaken to analyze this trend. The results, shown in Fig. 1 b), revealed that the varying power levels of the pulse envelope generally develop different beam profiles. Acquiring clean on-axis conversion with a non-tophat pulse thus requires all of the power levels to give rise to an averaged profile that is predominantly on-axis, which in our configuration necessitated a displacement away from the focal plane. Future work will therefore be aimed at temporal pulse shaping to enable clean on-axis conversion at higher conversion efficiencies closer to the focal plane.

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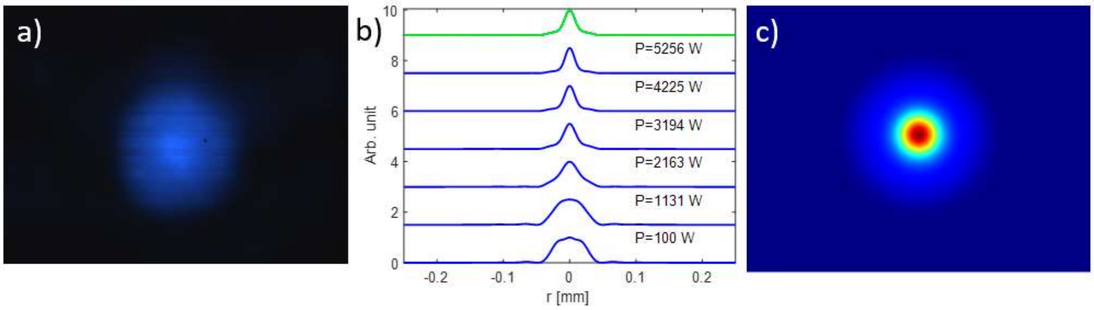

Fig. 1 a) Experimentally obtained on-axis beam. b) Simulated radial profiles at various power levels shown in blue. The green curve shows the resulting integrated profile, whose beam profile is shown in c).

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