Next, we have characterized the pulsed operation of the amplifier system. The average power of the seed pulses from the soliton fiber laser is about 1 mW after the stretcher fiber, with a corresponding energy of only 6.4 pJ. Thus, a preamplifier is necessary to boost the power up to 100 mW. After the power amplifier, the pulse energy is increased to 64 nJ at 156 MHz. The output spectra of the seed, preamplifier and power amplifier output are shown in Fig. 3(a). The pulse train is checked against multiple pulsing using a high-speed photodetector connected to an RF spectrum analyzer (with a combined bandwidth of 12 GHz) and a long-range (60 ps) autocorrelator. The net gain factor of the system is ~40 dB, and including the losses due to components and splices, the actual amplification factor is estimated to be >50 dB. As a result, we observe significant gain narrowing. After dechirping with a diffraction grating compressor, the pulses are characterized via intensity autocorrelation (Fig. 2(b)). The efficiency of the compressor is 25% owing to the poor quality of the grating. The full-width at half-maximum pulse duration is inferred to be 450 fs, assuming a Gaussian pulse shape. The pulse width is nearly twice the transform-limited pulse duration, which is limited by the onset of the self-phase modulation in the amplifier, as well as mismatch of third-order dispersion from the fiber stretcher and the grating compressor. The amplifier output shows excellent long-term stability in power, spectral shape and autocorrelation trace.

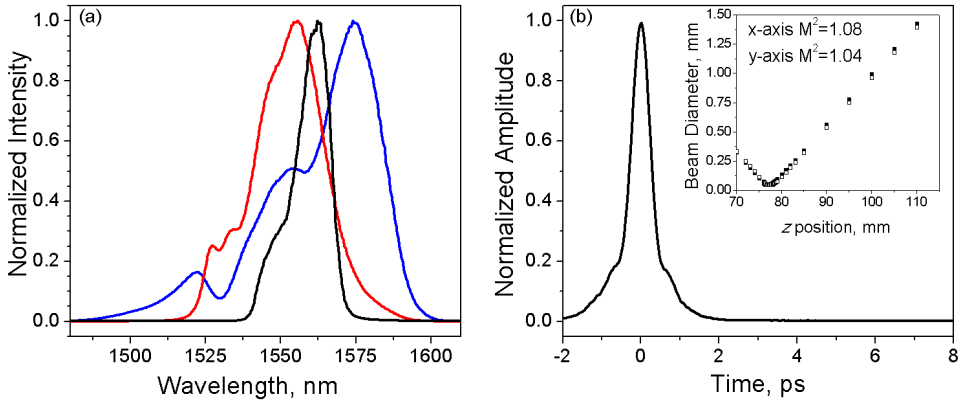


Fig. 3. (a) Measured optical spectrum of the seed (blue line), preamplifier (red line) and power amplifier output at 10 W (black line). (b) Intensity autocorrelation of the dechirped pulses at full amplifier output. Inset: Dependence of beam diameter at the 1/*e*-level on position, along with fitted $M^2$ values.

Finally, the beam quality also was verified, and the $M^2$ result is presented in Fig. 3. It confirms the excellent spatial properties of the beam with an $M^2$ value of 1.06.

## 4. Conclusions

In conclusion, we have demonstrated an all-fiber-integrated oscillator-amplifier system comprising of a 156-MHz oscillator operating in the soliton regime and seeding a fiber amplifier. Beam propagation everywhere in the system is in optical fiber and fiberized components until the final grating compressor. As such, the system is completely free of misalignment. The amplifier generates 10 W of average power at the collimator output, which is comprised of SMF-28. Therefore, the output is truly single-mode and diffraction limited. After dechirping, the pulse duration is 0.45 ps. We expect this system to be of use in various applications requiring high-power, high-repetition-rate pulses at an eye-safe wavelength.


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