











due to the gain narrowing effect. A small portion (3.4%) of the output power was reflected by a fused silica prism, and sent to a grating compressor to perform the pulse compression. The pulse width can be optimized to around 800 fs at both 0.5 kW and 1.05 kW amplified power levels. The autocorrelation traces are shown in Fig. 8(b). Output beam quality at the highest output power was evaluated. Figure 9 is a screen shot from  $M^2$  measurement results. The best-fit  $M^2$  values were 1.117 (parallel) and 1.12 (perpendicular). The insert in Fig. 9 shows a beam profile image.

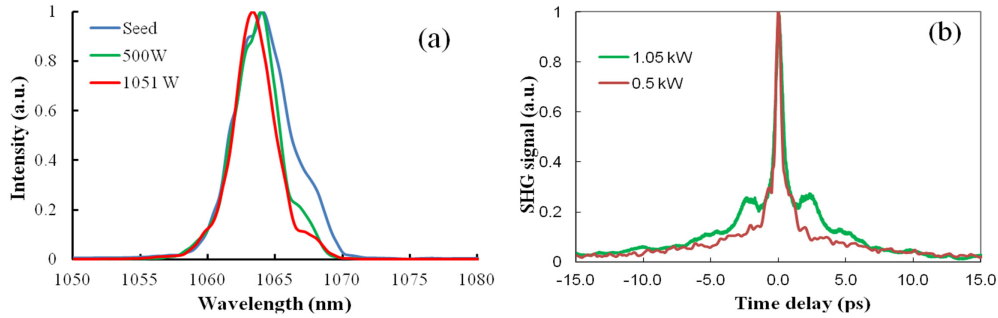


Fig. 8. (a) Spectra of seeding laser and amplified output at various power levels; (b) Autocorrelation trace of the output beam with various amplified average power.

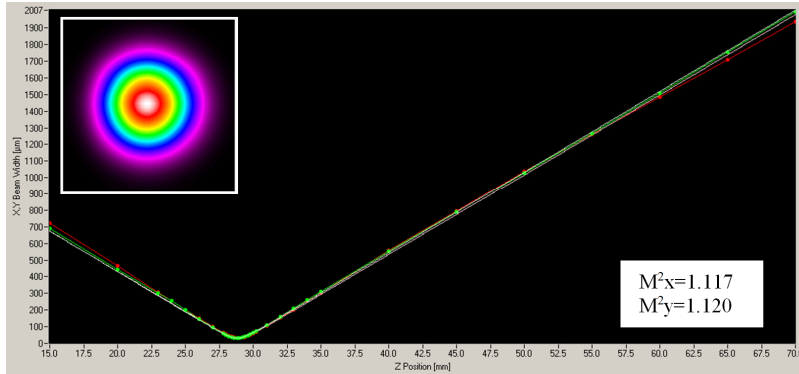


Fig. 9. Screen shot for  $M^2$  measurements: Beam diameters as functions of distance from laser beam waists. Insert is an image of 2D beam profile.

## Conclusions

In conclusion, we demonstrated two chirped pulse amplification systems to obtain mJ level high energy and kW level high average power femtosecond outputs at wavelength of 1  $\mu\text{m}$ , by seeding with commercial high energy or high power femtosecond fiber lasers. In the high energy laser system, amplified pulse energy of 1.05 mJ (0.85 mJ after pulse compressor) and pulse duration of 705 fs were generated from a Yb-doped ultra large-core single-mode rod-like PCF, seeded with a 50  $\mu\text{J}$  chirped pulse fiber laser. In the high average power system, an average power of 1052 W was obtained from the final stage LMA fiber amplifier, seeded with a 50 W chirped pulse fiber laser. This work provides a breakthrough in developing a compact, stable and low cost high energy ( $> 1$  mJ) and high power ( $> 1$  kW) femtosecond fiber laser system. Moreover it lays out a solid foundation towards achieving simultaneous high energy (mJ) and high power (kW) all fiber based femtosecond fiber laser system.

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