

# High Power Ultrafast Fibre Laser in the 920 nm Spectral Range

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**Abstract:** We describe an ultrafast Nd-doped fibre laser capable of generating 170 fs pulses in the 920 nm spectral range with output power of 0.8 W.

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OCIS codes:

High power fibre lasers based on double-clad fibre technology have become a universal tool for a variety of applications ranging from sensing and range finding with average powers of several watts to metal welding in car manufacturing when several kW of cw power was delivered by a single fibre [1]. Such unprecedented growth of output power has triggered further fibre development to extend both the spectral range and possible applications of fibre lasers. One of the most impressive features of fibre lasers is their ability to produce clean ultrashort pulses at a repetition rate identical to that of solid state lasers. Extremely high efficiency of ultrafast fibre lasers combined with virtually unlimited output power makes them almost ideal laser source in many applications (micromachining, homeland security, fundamental study etc) that were traditional dominated by Ti:Sapphire lasers.

Recently we have reported a tunable fibre laser operated in the 900 nm spectral band [2] with output power of a few mW. In this paper we present further developmentst of this system and report a 170 fs fibre system with output power as high as 800 mW at a wavelength of 927 nm.

Fig.1 shows the layout of the laser system which is based on a master oscillator – power amplifier (MOPA) configuration.

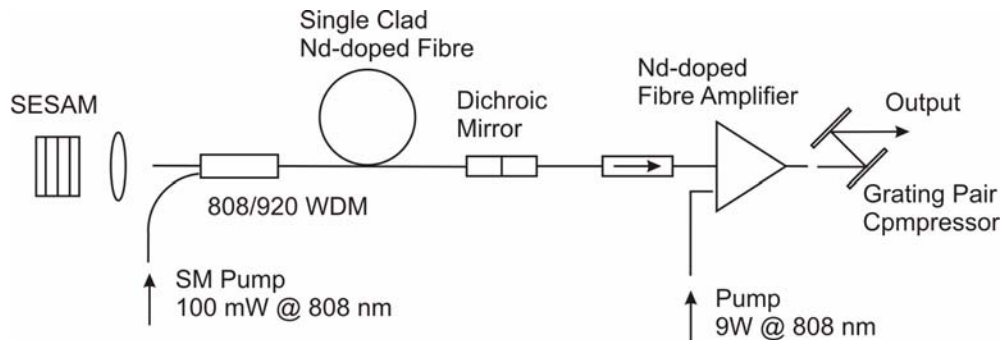


Fig.1 Layout of the fibre laser

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The master source is a core-pumped passively mode-locked Nd-doped fibre laser. The laser is pumped by a pigtailed single mode laser diode operating at a wavelength of 808 nm with maximum output power of 100 mW. The length of doped fibre (INO Nd103) was around 0.8m. The laser was pumped through a custom-made 808 / 920 nm fused WDM coupler. The laser cavity was formed by a semiconductor saturable absorber mirror (SESAM) from one end and a dichroic dielectric mirror with reflectivity of 80% deposited on the endface of the doped fibre. Wavelength selective properties of the WDM and dichroic mirror were enough to promote 920 nm lasing and suppress unwanted radiation at 1064 nm.

The threshold for mode-locking operation was 45 mW and the laser produced clean, nearly transform-limited 6 ps pulses at a pump current of 60 mW (see Fig.2). Further increase of pump power resulted in multi-pulse operation when more than one pulse circulates inside the laser cavity. This fact was a clear indication that the laser operates in a regime when the energy of the generated pulses is clamped by the combined action of nonlinearity and dispersion of both the silica fibre and the semiconductor saturable absorber.

The output power at a fundamental repetition rate of 50 MHz and in a single pulse regime was approximately 2 mW.

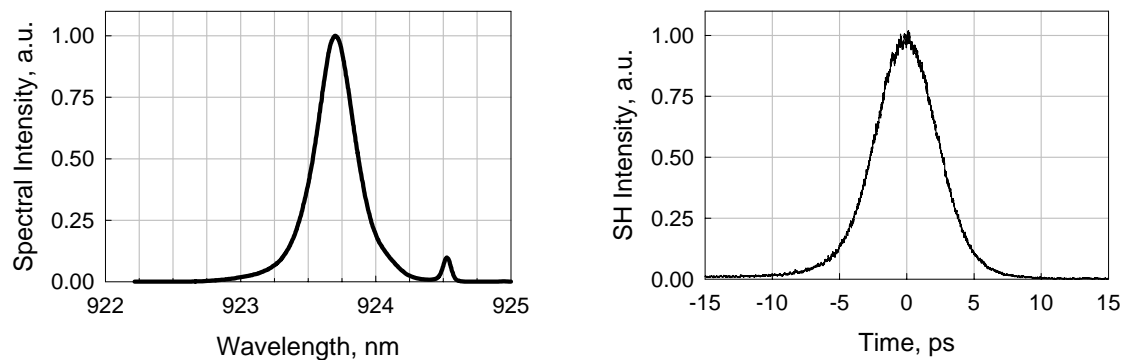


Fig.2 Spectrum (a) and autocorrelation (b) at the output of the master source

For practical applications such as frequency doubling or pulse compression in an external grating pair, it is desirable to have linearly polarized output radiation. One way to achieve it is to make the laser cavity using polarization maintaining components. In many cases it is not a very practical way forward due to the lack of suitable components. However in our case the master laser produces nonlinear pulses with polarization uniform across the entire pulse and therefore the polarization may be corrected at the output by a suitable set of phase plates.

The high power fibre amplifier was based on Nd-doped fibre. The use of a W-type refractive index profile of the doped core resulted in a finite cut-off wavelength of the fundamental mode which has allowed us to suppress the unwanted gain at 1064 nm [3,4].

The amplifier was 9 m long and pumped by a high brightness pump module PUMA [4] capable of delivering up to 9 W of optical power at 808 nm. The pump delivery fibre had a 105  $\mu\text{m}$ , 0.22 NA core. The master source and high power amplifier were connected via a high power isolator with mechanical connection between the isolator and the master source. This measure had allowed us to achieve low coupling loss between master source and isolator and at the same time preserve high reflectivity of the dichroic mirror. The output fibre of the isolator was fusion spliced to the input of the fibre amplifier.

The fibre amplifier was pumped in a co-propagated scheme and the pump absorption over 10 m was 6 dB, so that the absorbed pump power was around 7W

At full pump power, the maximum output power available at 927 nm was 1.4 W. The peak power of the amplified pulses exceeded 3 kW

Since the amplifier length is much shorter than the dispersion length of the amplified pulses, (which is around 2 km), the pulse temporal width was unchanged at the output of the amplifier, whereas spectrally the pulses became very broad due to the effect of self-phase modulation in optical fibres.

Strong self-phase modulation and linear chirp almost across the whole pulse make this configuration very attractive for pulse compression using bulk grating pairs where high gain and short amplifier length result in a relatively short distance between gratings. The grating pair consisted of two gold

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coated, 1200 lines/mm gratings with diffraction efficiency of approximately 85%. To maximize the output power of the grating pair, a set of quarter and half-wave plates was used at the input to the compressor. It is worth noting that despite the fact that both master source and power amplifier was based on non-PM components, the output polarization was remarkably stable and the laser did not require polarization adjustment as soon a suitable polarization was set. The total power after the grating pair was 800 mW and the power loss can be attributed to both loss at the gratings and slightly non-uniform state of polarization across the amplified pulse. By adjusting the distance between the gratings we were able to compress the amplified pulses to 170 fs to reach a 35-fold compression and reach peak power of the amplified pulses as high as 120 kW.

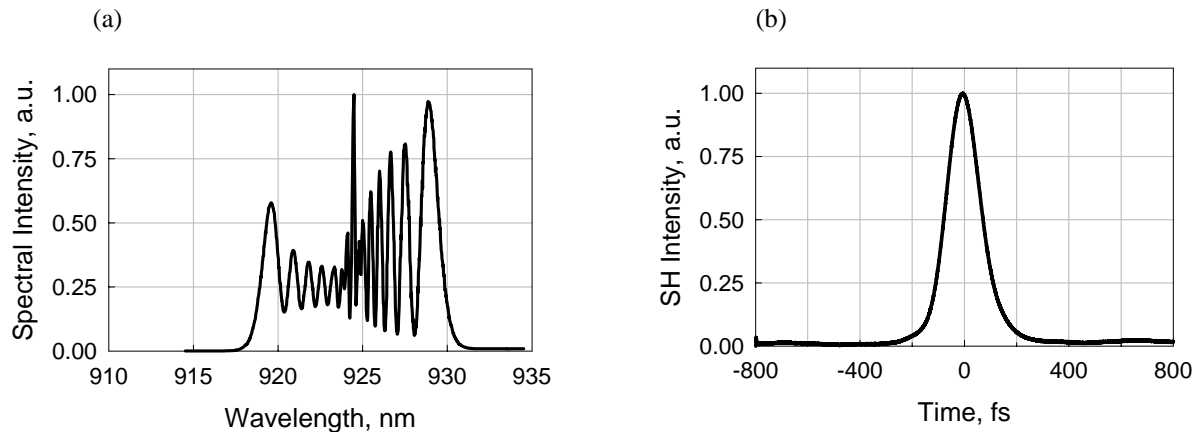


Fig. 3 Spectrum (a) and autocorrelation (b) of the amplified pulses

In summary, we have demonstrated a compact, practical fibre laser operating in the spectral range of 920 nm. This spectral range is traditionally covered by ultrafast Ti:Sapphire lasers, whereas the developed fibre laser being much more compact and efficient offers parameters close to those of traditional solid state counterparts.

Furthermore, this 920nm MOPA configuration lends itself to the generation of high power, quasi CW blue light using nonlinear frequency conversion with a high efficiency.

## References

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