

Narrow linewidth picosecond source at 760 nm generating 50 nJ pulses using four-wave mixing

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Abstract: We have demonstrated an electronically controlled laser, generating 50 nJ picosecond pulses at 760 nm. The gain-switched pulses at 1032 nm are amplified in Yb-fiber and frequency converted in photonic crystal fiber using four-wave mixing. © 2022 The Author(s)

1. Introduction

Coherent Raman scattering (CRS) processes are appealing for microscopy as they provide the ability to perform label-free chemical imaging [1,2]. The versatility of CRS microscopy is appealing for applications such as biological imaging and chemical identification in pharmaceuticals. As a nonlinear process, CRS could require up to kW peak power picosecond pulses, often provided with Ti:Sapphire lasers or optical parametric oscillator-based sources, which are expensive and prone to misalignment.

Degenerate four-wave mixing (FWM) in photonic crystal fiber (PCF) provides an attractive solution for generating picosecond pulses in the 600 to 800 nm region. These sources are often configured as a master oscillator power amplifier (MOPA) followed by frequency conversion in PCF [3–8]. However, generating narrow linewidth pulses for high resolution CRS in photonic crystal fiber is challenging, due to large four-wave mixing (FWM) gain bandwidth and high PCF nonlinearity. A dispersive feedback cavity around the PCF can overcome these limitations [4], however the external cavity needs to be matched to the MOPA repetition rate. To provide flexibility with repetition rate, wavelength tunability, and robustness we present a diode-based laser source capable of generating 50 nJ picosecond pulses at 760 nm with an electronically controlled repetition rate. The initial pulse is generated by gain-switching a 1032 nm diode producing 50 ps pulses. These pulses are amplified in Yb-fiber stages and passed through 90 cm of LMA-5 PM PCF. A narrow linewidth output of 0.06 nm at 760 nm (signal) is generated by seeding the four-wave mixing with 1 mW of narrow line-width CW signal at 1607.2 nm (idler).

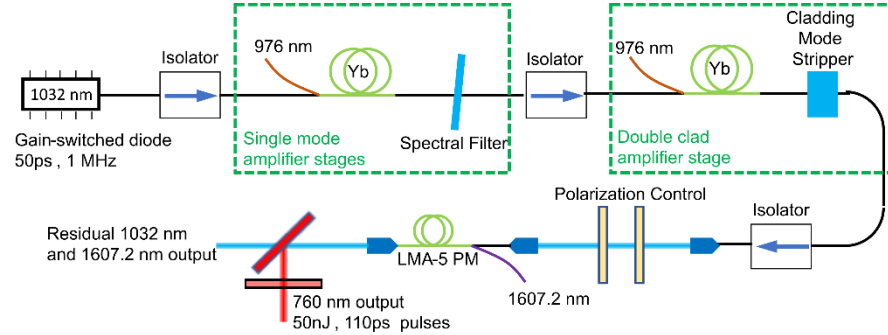


Figure 1: Schematic of the 760 nm picosecond tunable repetition rate pulsed source. 50 ps pulses generated by the gain-switched diode are amplified in the Yb-fiber stages and coupled into 90 cm of LMA-5 PM PCF along with a 1 mW seed at 1607.2 nm. The collimated output from the PCF is spectrally filtered to obtain 110 ps, 50 nJ pulses from the laser.

2. Laser design and results

A schematic of the laser system is shown in Figure 1. The initial pulses for the source are generated using a gain-switched diode at 1032 nm with a repetition rate of 1 MHz. The gain-switched driver generates 50 ps pulses with a spectral bandwidth of less than 0.05 nm (FWHM) (Figure 2A) and a peak power of 200 mW. These pulses are amplified in three single mode amplification stages and a double clad amplification stage producing an average power of 750 mW. A grating based narrow spectral filter before the double clad amplification stage ensures rejection of amplified spontaneous emission from the single-mode amplification stages. After the double clad stage, the 1032 nm output undergoes polarization control and is coupled into a polarization maintaining wavelength division multiplexer (WDM) that combines the 1032 nm output with a 1 mW CW seed at 1607.2 nm. The output of the WDM is cold spliced onto 90 cm of LMA-5 PM PCF. The output from the PCF is collimated and the 760 nm signal (Figure 2B) is separated from the residual pump and idler outputs using a dichroic and a bandpass filter.

The nonlinearity of the PCF and the gain bandwidth of the FWM, generates a broadband multiple octave spanning output (Figure 2C) from 450 to 1620 nm, without the 1 mW seed at the idler wavelength. While this broadband

background remains with a 1 mW seed at 1607.2 nm, it is 30 dB below the signal at 760 nm. Without the bandpass filter centered at 760 nm, the average power from the PCF at wavelength below 805 nm is approximately 120 mW. Upon filtering further with a 10 nm bandpass filter, we obtain a collimated output with an average power of 50 mW with 110 ps pulses (Figure 2B) at 1 MHz repetition rate corresponding to pulse energies of 50 nJ. The spectral linewidth of the signal at 760 nm with the seed at 1607.2 nm is 0.06 nm (FWHM).

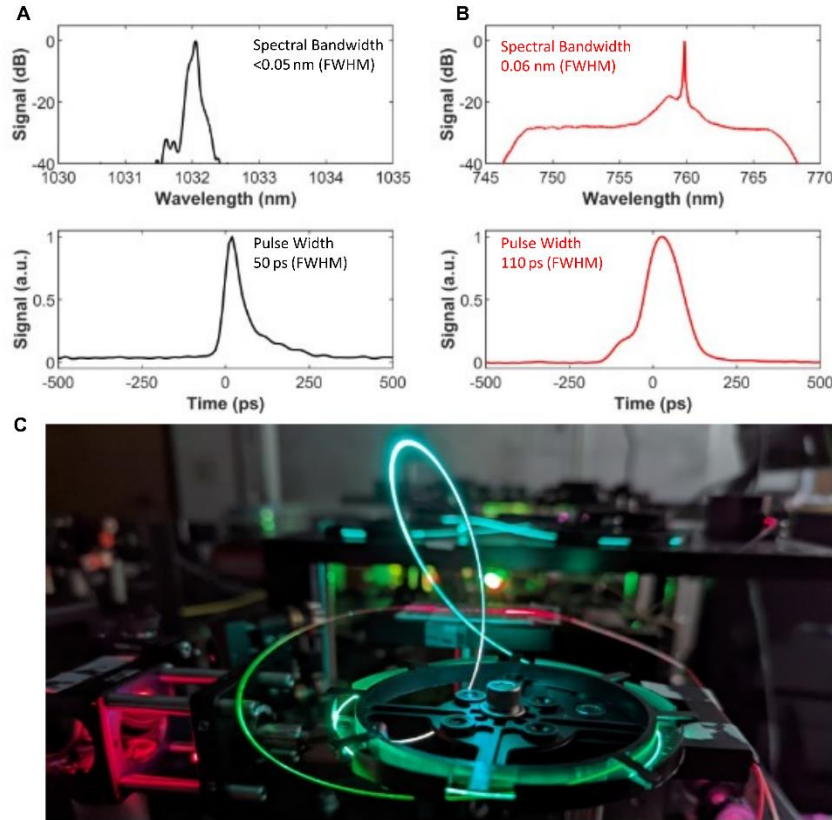


Figure 2: (A) Spectral and temporal output from the gain switched diode indicating a spectral width of less than 0.05 nm and pulse width of 50 ps (FWHM). (B) Spectral and temporal output after filtering the 760 nm signal indicating a spectral width of 0.06 nm and pulse width of 110 ps (FWHM). (C) Long exposure image of supercontinuum generation in the PCF.

3. Conclusion

We have demonstrated a diode-based tunable repetition rate, robust laser source producing 50 nJ pulses at 760 nm. Pulses generated at 1032 nm by gain switching are amplified in Yb-fiber and frequency converted in 90 cm of LMA-5 PM PCF. Without the use of an external dispersive cavity, a narrow linewidth of 0.06 nm is obtained at 760 nm by simply seeding the FWM process with 1 mW of power at the idler wavelength,

4. References

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