Sub-300 fs, 0.5 mJ pulse at 1kHz from Ho:YLF amplifier and Kagome pulse compression

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Motivation

- Development of driver for mid-IR Optical Parametric Amplifier (OPA)
  - Long wavelength 2 µm pump source
  - High energy CPA scheme (≈ 2mJ, 3.4 ps @ 1kHz)
- Sub-ps pulses for white light seed generation
- Self compression for 3.4 ps, 0.5 mJ pulse in Kagome fibre
- High Harmonic Generation: \( U_p \sim I_L \lambda^2 \)
- THz generation
Previous Results

  - First Ho:YLF Regenerative Amplifier (RA)
    - Seed source: Ho:YLF based oscillator $\tau \approx 250\text{ps}$
    - RA + SPA: $7.2\text{mJ}, 1\text{kHz}, 300\text{ps}$

  - Seed source: 2 stage OPA at $2.1\mu\text{m}$. $E \approx 0.7\mu\text{J}$
  - Ho:YAG RA: Anti-gain narrowing filter: $3\text{mJ}$ uncompressed, $5\text{kHz}$, $530\text{fs}$

  - Seed Source: Tm-Ho Amplifier seeded by frequency shifted Er oscillator
  - Ho:YLF RA + cryo cooled Ho:YLF amplifier: $39\text{mJ}, 100\text{Hz}, 10\text{ps}$
This Work

- Seeding of Ho:YLF regenerative amplifier with compact home built Ho: fibre oscillator $E_{\text{seed}} \approx 60 \text{ pJ}$ and $E_{\text{out}} \approx 1.1 \text{ mJ}$,

- Amplified gain of $10^7$

- Shortest pulse duration achieved with Ho:YLF regen $t \approx 3.4 \text{ ps}$

- Demonstration of pulse self compression of the output using Kagome fibres

- Demonstration of self compression of 3.4 ps long pulses using 2 μm pulses to sub-300 fs
Comparison of 2-μm gain media

<table>
<thead>
<tr>
<th>Host</th>
<th>(\lambda_{\text{abs}}) (nm)</th>
<th>(\lambda_{\text{em}}) (nm)</th>
<th>(\sigma_{\text{abs}}) ((10^{20}\text{cm}^2))</th>
<th>(\sigma_{\text{em}}) ((10^{20}\text{cm}^2))</th>
<th>(T_c) (Wm(^{-1})K(^{-1}))</th>
<th>(\tau) (ms)</th>
<th>(n_2) ((\text{m}^2/W))</th>
<th>Reference</th>
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</table>

3. L. Fornasiero, *Conference. Advar*
Schematic of self-seeding two stages OPA

CW Tm: Fiber Laser 10W
~ 60pJ, 300ps, 2051nm

Ho: Fiber Oscillator
Home-built
~ 1 nJ, 160 fs, 2060nm, 35mW

CVBG Stretcher

Ho: YLF Regen + Single Pass Amplifier (SPA)
~ 1.2mJ, 2051nm

Commercial system

Kagome HC-PCF Compressor

0.5 mJ, 3.5ps

Mid-IR OPA

White light generation

CVBG Compressor
~ 1.1mJ, 3.5ps

Output

Schematic of self-seeding two stages OPA
Results: Regen + SPA

Oscillator Spectrum: FWHM 40.2 nm
Seed (after stretcher): FWHM 8.2 nm
Amplified (after regen): FWHM 2.5 nm

SHG FROG results
Nonlinear Pulse Compression

- Spectral broadening in conventional fibres
- Spectral broadening in noble-gas filled hollow capillaries
- Hollow Core Photonic Crystal Fibres (HC-PCFs)
  - Kagome lattice HC-PCFs: Inhibited Coupling
    - Extremely low core-clad power overlap
    - Low transmission loss
    - Dominance of anomalous dispersion over large section of transmission widow
Previous Results


- Input: 1.5 µm, 850 fs, 105 µJ
- 20 cm 19-cell Kagome fibre 3.5-bar He-filled
- Compressed to 300 fs


- Input: 1.5 µm, 740 fs, 18 µJ
- 66 cm 19-cell Kagome fibre 13-bar Ar-filled
- Compressed to 88 fs


- Input: 800 nm, 100 fs, 8 µJ
- 11 cm 19-cell Kagome fibre 15-bar Kr-filled
- Compressed to 10 fs

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- Input: 1.8 µm, 80 fs, 35 µJ
- 20 cm 19-cell Kagome fibre 4-bar Xe-filled
- Compressed to 4.5 fs
Kagome HC-PCF Compressor

Transmission Efficiency > 90%
Results: 19-cell

Spectral evolution for 19-cell fibre

Measured

Retrieved

Pulse Duration (ps)

Intensity (a.u.)

Phase (\pi \text{ rad})

290 fs

Intensity (a.u.)

Phase (\pi \text{ rad})
Conclusion

Summary

- Simple and Compact seeding of Ho: YLF regenerative amplifier
- 1.1 mJ output from Ho: YLF amplifier + SPA seeded with Ho:fibre oscillator.
  Stretched and compressed using CVBG
- Demonstration of self-compression 2 micron pulses using Kagome HC-PCFs
- 3.4 ps long pulses at 2050 nm was compressed to ~300 fs

Outlook

- Further optimization:
  - Gas pressure, fibre length and input pulse duration
- Pumping and seeding MIR-OPCPA

Ho: YLF Regen
2050 nm
1.1mJ, 3.5ps

Kagome HC-PCF Compressor
Mid-IR OPA
Output

White light generation

Output
Thanks for your attention