Inline Amplification of Mid-Infrared Intrapulse Difference Frequency Generation

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We demonstrate an all inline two stages mid-infrared (MIR) source based on intrapulse difference frequency generation (iDFG) and subsequent optical parametric amplification (OPA), with pump recycling. The source is driven by a nonlinearly compressed high-energy Yb-doped-fiber amplifier delivering 7.4 fs pulses at a central wavelength of 1030 nm, at a repetition rate of 250 kHz [1]. It delivers 1 µJ 73 fs (sub-three optical cycles) pulses at a central wavelength of 8 µm, corresponding to a total efficiency of 2 %. The amplified MIR central wavelength is tunable over more than one octave ranging between 4-8 µm.

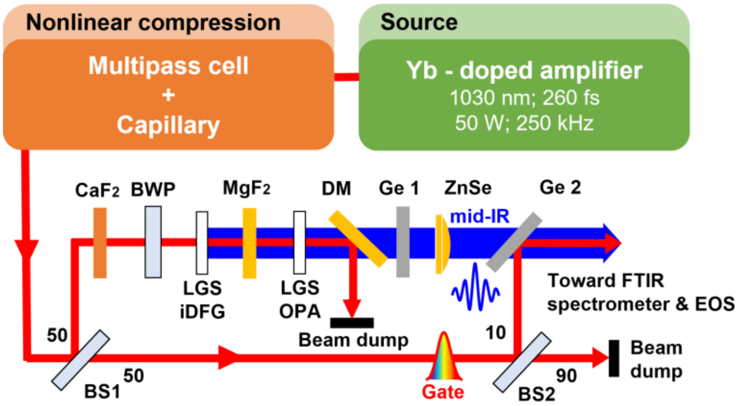

Fig. 1 Schematic of the experimental setup. The pump beam is sent on the 50/50 beamsplitter (BS1). The reflected driving pulses go through calcium fluoride (CaF2) windows to adjust the chirp and the bichromatic waveplate (BWP). Then, they drive the generation in the XY LGS crystal and the amplification in the XZ LGS crystal. The MIR radiation is filtered by a dichroic mirror (DM). A germanium plate (Ge 1) is inserted to adjust the GDD of the MIR and a zinc selenide (ZnSe) lens is used to collimate it. A magnesium fluoride (MgF2) crystal is inserted to adjust the delay. The transmitted pulses (gate) are sent to a second beamsplitter (BS2) and to a second germanium plate (Ge 2) to recombine the gate and the MIR for EOS measurement.

At the iDFG stage output, the 1030 nm residual driving pump pulses are recycled to transfer part of its energy to amplify the MIR pulses in the OPA stage. As shown in Fig. 1, this ultrafast MIR source combines a chirp-management calcium fluoride crystal, a bichromatic waveplate (BWP) [1,2], a type II $LiGaS_2$ (LGS) crystal-based iDFG stage, a delay-management magnesium fluoride birefringent crystal, and a type I LGS crystal-based OPA stage. The high efficiency of the source over the whole MIR central wavelength tunability range is ensured by a precise control of the different nonlinear processes involved in each stage. The setup allows an independent management of the different wavelength delays to obtain perfect interaction pulses overlap in the OPA step.

This implementation results in several key features: (i) all pump photons are polarized adequately to be enrolled in the iDFG process (ii) the long wavelength pump photons that have been amplified in the iDFG stage are recycled and used to pump the OPA stage after a resynchronization stage (iii) the architecture is all inline, with no spatial and temporal overlap alignment involved. This architecture is compact and simple, combining high energy, broad bandwidth, and high repetition rate, particularly suitable for nonlinear time-resolved 2D spectroscopy experiments and drive High Harmonic Generation (HHG) in solids.

References

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