Multistage parametric light amplification method and amplifier

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SUMMARY

The present technology involves methods for improving efficiency of optical parametric amplifiers (OPAs). Methods do not require complex amplification schemes, they are versatile and are suitable for high-power beams and pulses of various duration, do not generate unnecessary heat. Experiments have shown that these techniques can improve conversion efficiency in an OPA up to 2 times, while maintaining excellent beam quality.

BACKGROUND

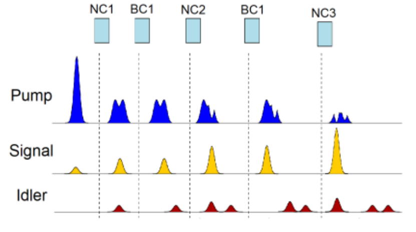
OPAs are valued for their ability to generate high power light beams at tunable wavelengths. During parametric amplification, the pump beam is converted into signal and idler beams. However, it is impossible to convert all the energy of the pump wave to signal and idler in a regular single-stage amplifier, because of variations of local intensity in the beam, which result in spatially- and temporally-varying conversion rate.

Several methods have been proposed to limit back-conversion: by designing a periodically oriented crystal structure rotated at a large angle in the direction of propagation of signal and pump waves; by constructing a multi-path parametric amplifier and preventing the idler wave from passing through the resonator; or by doping parametric amplification crystal with a substance that causes absorption of the idler wave. These methods have drawbacks, such as incompatibility with high-power lasers, high complexity of the amplifier scheme, limited accessible wavelength range or strong crystal heating.

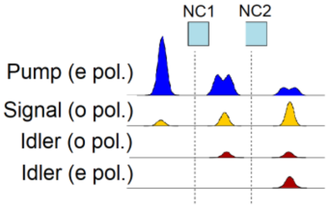
TECHNOLOGY

We offer several compact and simple ways to minimise back-conversion, which is often the limiting factor for OPA efficiency:

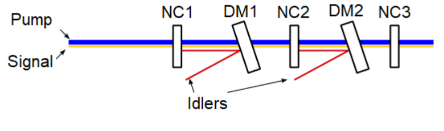
- Dividing the amplification medium into several parts with pairs of nonlinear and birefringent crystals. Birefringent crystals, placed after nonlinear crystals, delay the idler wave so it does not overlap with either the pump or signal waves, thus preventing back-conversion, while keeping signal and pump waves synchronised.



- An implementation, suitable for long pulses, is based on combining amplification crystals of ordinary and extraordinary polarisation so that the idler wave is generated in different polarisation states.



- Eliminate the idler wave by combining nonlinear crystals with dichroic mirrors. There could be several pairs in the scheme. This method can also be combined with the previous methods.



These methods can be applied with any known nonlinear crystals, thus being applicable in different wavelength ranges. As these methods avoid periodically-poled crystals, they can be used with high-energy pulses.

TECHNOLOGY READINESS LEVEL

1 – 2 – 3 – 4 – 5 – 6 – **7** – 8 – 9

Prototype demonstration

INTELLECTUAL PROPERTY

Patent application published EP3798723A1.
Technology developed at Vilnius University.

BENEFITS

- Substantial improvement of amplification efficiency of OPA while preserving beam quality.
- Methods can be applied without highly specialized non-standard optical elements.
- Methods are suitable for high-power pulses of various duration.
- Proposed methods could be combined in a single OPA system to reach maximum efficiency.

APPLICATION

Technology can be used specifically for improving the energy efficiency of OPA systems. Powerful OPA can be used for various applications:

- Nonlinear optics research;
- Spectroscopy;
- Microscopy;
- Micro-structuring;
- Material modification;
- Other application areas of high-energy ultrafast lasers.

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