Multimillijoule Picosecond Regenerative Differentiator-Amplifier

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CLEO/QELS 2008
San Jose, CA
4–9 May 2008
12-mJ picosecond pulses have been generated in a regenerative amplifier with volume Bragg grating (VBG)

Summary

• Optical differentiation in a diode-pumped regenerative amplifier (DPRA) occurs when the VBG reflectivity peak is temperature-detuned from the central injection wavelength.

• A step-like pulse injected into the DPRA differentiator produces a short pulse, whose width is defined by the sharp edge rise time.

• Multimillijoule 150-ps FWHM pulses have been generated in the DPRA by a temperature-detuned VBG without mode locking.
Traditional ways of obtaining energetic picosecond pulses involve mode-locking or a Q-switched microchip laser.

We demonstrate a new way of generating energetic picosecond pulses by using a diode-pumped differentiator-amplifier with an intracavity VBG.
Volume Bragg gratings represent a new class of spectrally selective optical elements

VBG’s are recorded in photothermo-refractive Na-Zn-Al silicate glass doped with silver, cerium, and fluorine.*

VBG’s have
- higher spectral and angular dispersion than dispersive elements previously used
- high diffraction efficiency (>99.5%)
- high damage threshold (>20 J/cm² for nanosecond pulses)

VBG’s are stable at elevated temperatures.

A VBG has a high reflectivity >99% that makes it possible to be used as a DPRA resonator spectrally selective mirror.

Reflectivity of the VBG used in this experiment was 99.7% with a 240-pm FWHM bandwidth.

Spectral filtering in the DPRA resonator benefits from the large number of reflections off of the VBG over many round-trips.
A Nd:YLF DPRA with a temperature-tuned VBG as a resonator end mirror has been demonstrated. The VBG reflectivity peak can be temperature-tuned around an injected wavelength with the rate of 10 pm per degree C.

DPRA a with a VBG output beam profile corresponds to TEM$_{00}$ mode.

The VBG reflectivity peak can be temperature-tuned around an injected wavelength with the rate of 10 pm per degree C.
When injected with a Gaussian pulse the DPRA produces a slightly shorter pulse due to gain saturation.

**Q-switched laser**

**DPRA with VBG**

**Δλ = 0 pm**

**DPRA**

4.9-ns FWHM; 250 nJ

3.75-ns FWHM; 12 mJ
The DPRA works as a differentiator when the VBG temperature is detuned from the injected-pulse center wavelength.*

* A. V. Okishev et al., in Advanced Solid-State Photonics on CD-Rom (Optical Society of America, Washington DC, 2008), Paper WE32.

A step-like pulse is required to produce a short pulse with the full width of the order of the step rise time.
Wavelength detuning by 20 pm is enough to provide differentiation in the DPRA.

VBG reflectivity difference of ~0.3% per round-trip (total number of round-trips is 50) combined with $10^8$ DPRA gross gain provides enough discrimination to not amplify the center wavelength, making DPRA an optical differentiator.
A step-like pulse shape with a sharp leading edge was produced with an SBS-based steepener (SBS mirror).

4.9-ns FWHM; 2.8 mJ

3-ns FWHM; 300-ps leading edge; 1.2 mJ (further attenuated to 250 nJ for DPRA injection)
The DPRA with VBG tuned to the injection central wavelength produces nanosecond pulses from the step-like pulse.

- **Q-switched laser**
- SBS pulse steepener
- DPRA with VBG

**Graphs:**
- **Left graph:**
  - 3-ns FWHM;
  - 300-ps leading edge;
  - 250 nJ

- **Right graph:**
  - 1.25-ns FWHM;
  - 12 mJ

**Diagram notes:**
- $\Delta \lambda = 0$ pm
- Gain saturation shortened
150-ps FWHM, 12-mJ pulses are produced in the DPRA after differentiation of a step-like pulse.

A step rise time as short as 100 ps can be produced by an SBS mirror that potentially makes it possible to generate ~50-ps FWHM pulses in the DPRA.
Summary/Conclusions

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- A step-like pulse injected into the DPRA differentiator produces a short pulse, whose width is defined by the sharp edge rise time.

- Multimillijoule 150-ps FWHM pulses have been generated in the DPRA by a temperature-detuned VBG without mode locking.