78

OSA Proceedings on

ADVANCED SOLID-STATE LASERS

Volume 24

Edited by
Bruce H. T. Chai and Stephen A. Payne

Proceedings of the Topical Meeting
January 30-February 2, 1995
Memphis, Tennessee

Sponsored by
Optical Society of America

In cooperation with
IEEE/Lasers and Electro-Optics Society

Optical Society of America
2010 Massachusetts Avenue, NW
Washington, DC 20036-1023
(202) 223-8130

Long Pulse Optical Parametric Oscillator based on Bulk Periodically-Poled $LiNbO_3$

W. R. Bosenberg, A. Drobshoff, and D. C. Gerstenberger
Lightwave Electronics Corporation, Mountain View, CA 94043
(415) 962-0755, Fax (415) 962-1661

L. E. Myers, R. C. Eckardt, M. M. Fejer, and R. L. Byer
E. L. Ginzton laboratory, Stanford University, Stanford, CA 94305

Introduction

OPOs are often grouped by their temporal characteristics, and recently 10 - 30 ns pulse, 100 fs - 1 ps pulse, and CW OPOs have received the most attention. Here, we report on a mid-infrared OPO driven by a unique pump architecture producing pulses in the 0.1 - 1 µs regime. This temporal regime offers the potential of narrower linewidths without the complexities associated with CW OPOs.

A key component to this work is a new nonlinear optical material, periodically-poled lithium niobate (PPLN). PPLN offers high nonlinear coefficients, low optical loss, and "engineerable" phasematching properties, which allows noncritical phasematching anywhere in its transmission range (0.35 - 4.2 µm). PPLN is quickly becoming the crystal of choice for low peak power mid-infrared frequency conversion.

PPLN Crystal Fabrication

The PPLN material was fabricated using an electric-field poling method [1]. Standard 0.5 mm thick $LiNbO_3$ wafers are poled using liquid electrodes. Straightforward lithographic and metallization processes produce a patterned electrode with period lengths suitable for nonlinear frequency conversion (15 - 30 µm). Applying an electric field of ~21 kV/mm permanently reverses the sign of the nonlinear coefficient in a pattern dictated by the electrode. The cross sectional view of a PPLN sample in Fig. 1 illustrates the straight vertical domain boundary walls through the 0.5 mm thick sample. The PPLN crystal used for this work was fabricated with a 31 µm quasi-phasematching period corresponding to signal and idler wavelengths of 1.67 µm and 2.93 µm. The PPLN sample exhibited the uniform structured poling over its 15 x 0.5 mm^2 aperture and 15 mm length necessary for efficient quasi-phasematching.

1.064 µm Pump Source

The pump source, shown in Fig. 2, has a CW, diode-pumped, Nd:YAG single frequency laser (700 mW), which is acousto-optically modulated to produce square pulses whose duration is variable between 150 ns - CW. The square pulse is sent through a 16 pass Nd:YAG amplifier [2], which increases the peak power to ~300 W. Gain saturation alters the square pulse to the shape shown in Fig. 3.

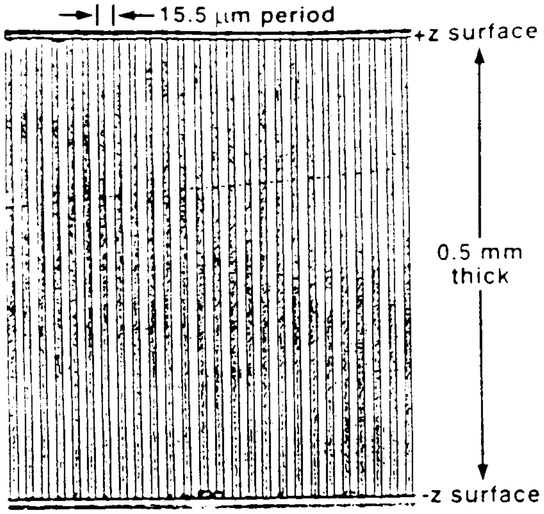


Fig. 1 Cross sectional view of a typical sample of PPLN after etching in HF to reveal the domain structure. Note straight and vertical nature of the domain boundaries.

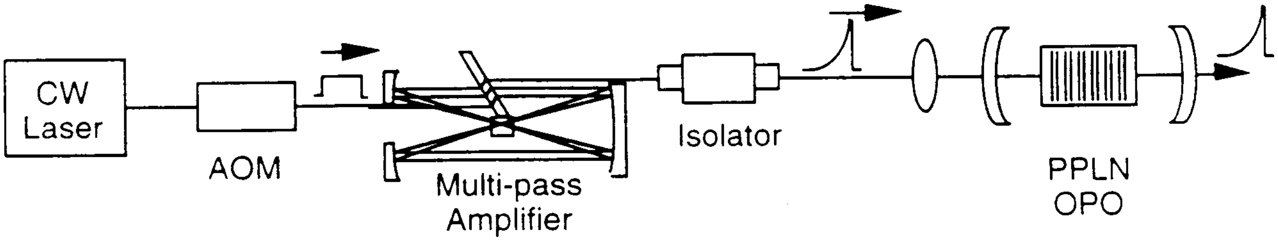
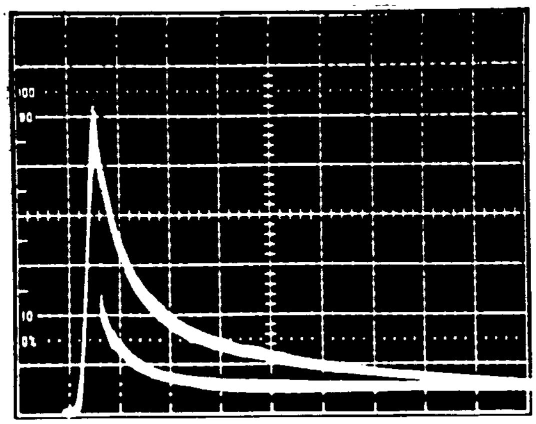


Fig. 2 This schematic of the experimental arrangement shows a CW laser (700 mW), acousto-optically modulated to produce square pulses. The square pulses are amplified to produce ~300 W of peak power with the pulse shape shown in Fig. 3 (upper trace). With this pump source, pulse duration, pulse shape, and repetition rate are readily variable.



Vertical Scale = 50 W/div

Horizontal Scale = 100 ns/div

Fig. 3 Pump pulse transmitted through the OPO with the OPO off (upper trace) and with the OPO on (lower trace). The diffence between the traces indicates the pump depletion. The OPO turns on after 30 ns, and the transmitted pump quickly saturates to ~26 W.

PPLN OPO and Results

The OPO resonator is a linear cavity whose mirrors have a 15 mm radius of curvature. Both the input coupler and the output coupler have reflectivities of 14 %, 98 %, and 12 % at the pump, signal, and idler wavelengths, respectively. The round trip feedback of the idler wave is ~1.5 %, which makes this OPO behave like a singly resonant oscillator when over three times above threshold [3]. The PPLN crystal apertures have antireflection coatings with reflectivities of 5.7 % and 0.8% at the pump and signal wavelengths. The estimated round trip loss at the signal wavelength is ~5.5 %.

At five times threshold (maximum pumping), the OPO ran robustly with a pump depletion of 43 %. The OPO threshold was measured to be 60 W (peak power). The saturated pump depletion level (shown as the flat section of the depleted pump pulse in Fig. 3) is ~26 W. By adjusting the width of the square pulse with the AO modulator, the OPO pulse duration could be varied over 150 - 600 ns. A maximum signal pulse energy of 5 μJ was recorded with a 52 μJ pump pulse at repetition rates of < 1 kHz. The OPO could be operated over repetition rates of 1 - 9 kHz.. Cavity losses from the input coupler and PPLN surfaces account for the difference between the pump depletion and measured output. Lower loss coatings would significantly increase the measured output.

The linewidth of the OPO was measured by directly looking at the transmission of its output through solid etalons 0.27 mm, 1.5 mm, and 7 mm in thickness. Depending on how close the cavity mirrors were to the PPLN crystal, the linewidth of the OPO varied from single longitudinal mode (<0.5 GHz) to 360 GHz. Intracavity etaloning is likely responsible for the very narrow linewidth operation, but our work shows that even a weak etalon (finesse < 1) is effective in limiting the linewidth of a low gain OPO. We expect that wrestling down the linewidth of this OPO will be much easier than for conventional short pulse (higher gain) OPOs. Use of weak intracavity etalons or perhaps just increasing the OPO rise time altering the shape of the pulse sent to the amplifier will yield narrow linewidths without the complexity associated with other techniques.

Conclusions

We have demonstrated a novel OPO which is based on PPLN. This device uses a unique pump source which generates pulses of varying temporal pulse shapes, and may prove advantageous for reducing the intrinsic linewidth of simple, two mirror cavity OPOs.

References

[1] L. E. Myers, G. D. Miller, R. C. Eckardt, M. M. Fejer, R. L. Byer, and W. R. Bosenberg, Opt. Lett. **20**, 52 (1995).
[2] H. Plaessmann, S. A. Re, J. J. Alonis, D. L. Vecht, and W. M. Grossman Opt. Lett. **18**, 1421 (1993).
[3] S. T. Yang, R. C. Eckardt, and R. L. Byer, J. Opt. Soc. Am. B **10**, 1684 (1993).