Quasi-Phase-Matched Gallium Arsenide for Mid-Infrared Frequency Conversion

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Abstract: Progress in processing low-loss quasi-phase-matched gallium arsenide crystals allows their excellent nonlinear properties to be employed in practical mid infrared devices. This presentation will address both crystal growth aspects and the most recent devices demonstrations.

Powerful coherent laser sources are needed throughout the mid-infrared region for a number of civilian or defense applications, exploiting either the atmospheric transmission windows, or the fingerprint of common molecules. Nonlinear optical materials play a key role as they permit the frequency down-conversion of mature high power near-infrared solid-state lasers into the mid-IR, where few direct laser solutions exist.

Gallium arsenide (GaAs) has excellent characteristics for parametric frequency conversion and is potentially one of the most attractive mid-IR nonlinear-optical materials. It has a large second-order nonlinear optical coefficient $d_{14} \approx 100$ pm/V, a wide transparency range of 1-16 µm, excellent mechanical properties, and high thermal conductivity [1]. The crystal is optically isotropic precluding birefringent phasematching, however with appropriate quasi-phase-matching (QPM) means, it can be used for numerous nonlinear optical applications.

The drawbacks of previous QPM GaAs devices based on diffusion bonding of thin GaAs wafers with periodic orientations [2], have been eliminated by the use of wafer-scale processing techniques for fabricating periodically-inverted (orientation-patterned) GaAs template substrates and Hydride Vapour Phase Epitaxy (HVPE) thick-film regrowth [3,4]. Atmospheric pressure HVPE allows growth rates of about 30 µm/h resulting in low doped layers with excellent optical properties. Careful growth parameters selection can preserve the periodic orientation of the template substrate to thicknesses in excess of 500 µm, thus enabling free space propagation of pump and signal beams.

After a brief review of past QPM GaAs research and achievements, this paper will focus on recent results obtained with thick OP-GaAs structures, as well as future prospects. Reproducible growth of 500 µm thick and 4 cm long samples with optical losses down to 0.01 cm^{-1} has enabled the demonstration of several mid-IR devices, including high average power pulsed mid-IR OPOs, and may soon permit the realization of a CW-pumped devices with large tunability [5-9].

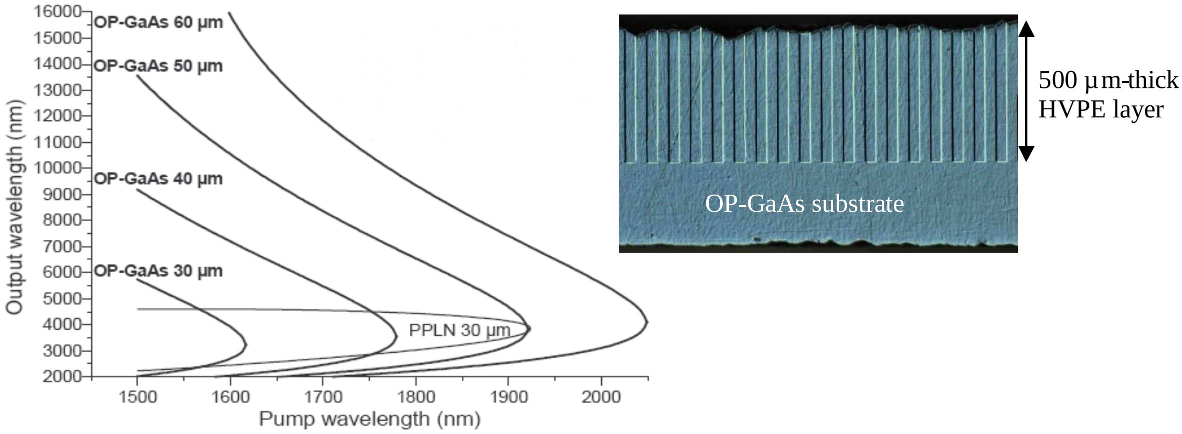

Figure 1: Mid-IR tunability of QPM OP-GaAs as a function of pump wavelength for different crystal periods(Left). Cross-section of a 500-µm-thick GaAs film grown over a 60 µm period OP-GaAs template (Right).

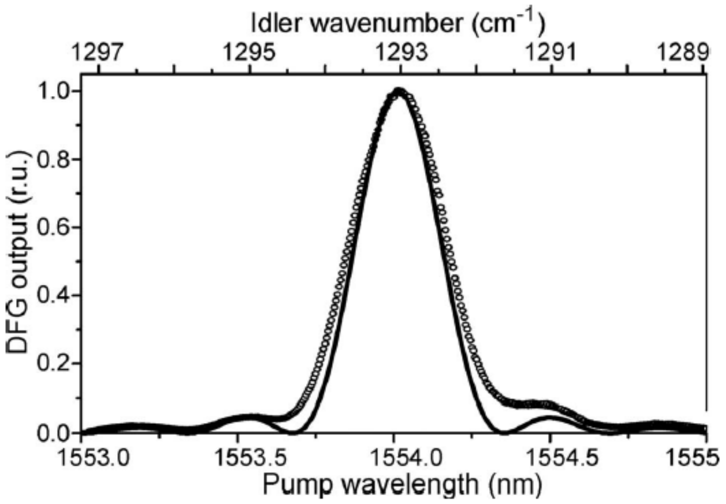

Figure 2: Difference frequency generation around 8 µm using Er (1.5 µm) and Tm (1.9 µm) CW fiber lasersources. The measured phase-matching curve is very close to the theoretical expected one and demonstrates the high quality of the 33 mm long OP-GaAs sample (after ref. 6).

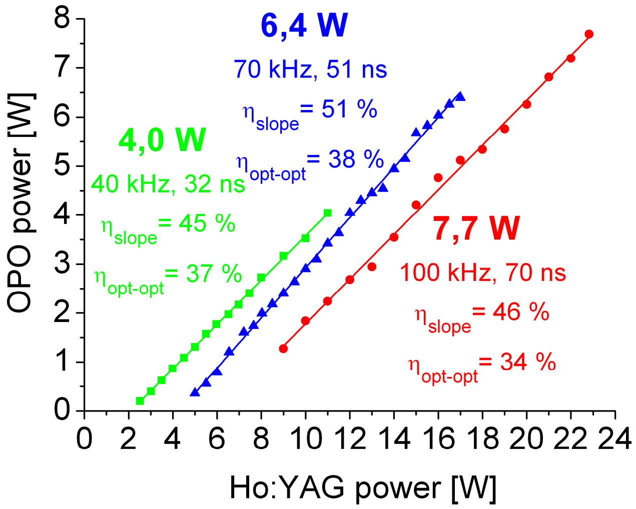

Figure 3: Output power in the 3-5 µm range of an OP-GaAs OPO pumped by a 2.1 µm Ho :YAG laser (after ref. 9).

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