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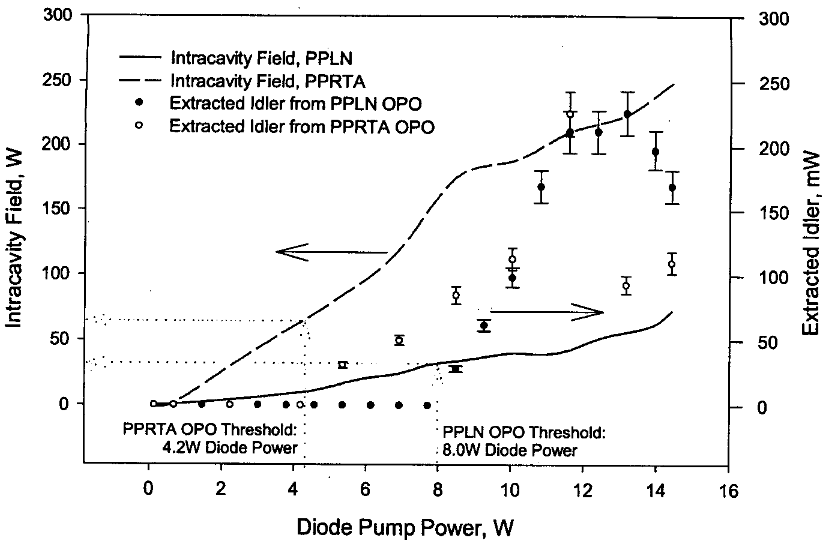
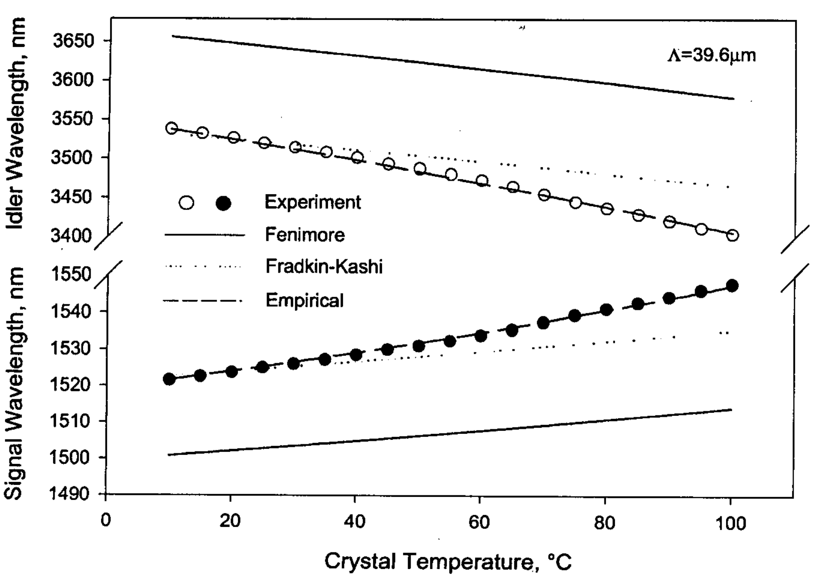


CThW4 Fig. 2. Extracted one-way idler output power and the one-way circulating intracavity pump-power at 1.064 µm as a function of the external pump power from the diode laser for the case of PPLN and PPRTA

Figure 2 summarises performance of the two devices. The PPLN OPO has a lower threshold in terms of intracavity pump-field, namely 30 W, compared to 65 W in the case of PPRTA; expected from its higher nonlinear coefficient. However, the external pump-power required to reach threshold is higher at 8W in the case of PPLN compared to 4.2 W in the case of PPRTA as a result of the higher slope efficiency shown by the intracavity field in the latter material, ascribed to the greater immunity of PPRTA to thermal lensing and aperturing compared to PPLN. In both cases the output power in the idler wave is in the range 200–250 mW at external pump-powers of the order of 12 W. (Unidirectional idler power, total generated power is twice this value). The spatial quality and temporal behaviour associated with the idler outputs are markedly different in the two cases. In PPRTA the idler mode is a stable, high spatial-quality mode close to TEM00, whereas in PPLN the spatial mode quality is both poor and unstable. In PPRTA the idler output from the OPO is true CW (intensity modulation below 5%), whereas in PPLN trains of relaxation-oscillation pulses are continually triggered leading to severe and noisy intensity modulation.

Figure 3 shows the temperature tuning characteristics of the PPRTA. At 20°C (room temperature), the observed signal/idler wavelengths agree closely with those predicted by the Sellmeier relations of Fradkin & Kashi.[2]

In PPLN we have investigated cavity geometries which allow low threshold operation (intracavity fields around 6 W), and enhanced idler outputs (350 mW at 12 W external pumping). We will report further on this and also on techniques for control of the relaxation oscillations that are still present in these improved geometries.



CThW4 Fig. 3. Experimental temperature tuning characteristics of PPRTA; upper trace (open circles) idler wave, lower trace (filled circles) signal wave. Calculated tuning characteristics based on Fradkin-Kashi[2] and Fenimore[3] are shown by dotted and solid lines respectively. In both cases, the temperature tuning characteristics were deduced using the (dn/dT) data of Karlsson.[4]

Acknowledgments

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CThW5 **5:45 pm**

Investigation of a diode-pumped intracavity optical parametric oscillator in pulsed and continuous wave operation

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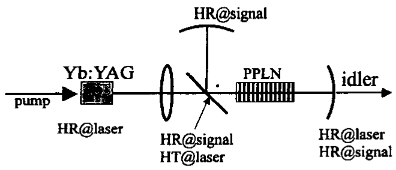
Cw and pulsed compact tuneable laser sources in the infrared have widespread scientific, medical and industrial applications. Such a laser source can be obtained by use of a diode-pumped intracavity optical parametric oscillator (IOPO).

Several investigations in this field have been published.[1,2] Here we report on a IOPO based on a Yb:YAG laser incorporating a periodically poled $LiNbO_3$ (PPLN) crystal inside the laser cavity to take advantage of the high circulating intracavity field. The Yb:YAG crystal is pumped by a reliable 940 nm fibre-coupled diode laser. The IOPO consists of a Yb:YAG crystal coated for HR at 1030 nm, an intracavity lens to generate a beam waist in the PPLN crystal, a dichroic mirror to separate the laser and signal fields and two end mirrors as shown in Fig. 1.

The 30 mm long AR-coated PPLN crystal



CThW5 Fig. 1. Schematic drawing of the IOPO.

contains 14 gratings with periods of 25.9 µm to 29.5 µm. OPO operation have been obtained in gratings with periods of 25.9 µm to 27.4 µm corresponding to signal wavelengths in the range 1340–1410 nm and idler wavelengths in the range 3800–4450 nm. The output power decreased with increasing idler wavelength due to absorption in the PPLN crystal. The signal output was coupled out of one of the two OPO end mirrors.

The output from the IOPO in cw and pulsed at 2 kHz repetition rate can be seen in Fig. 2. In cw operation the expected clamping of the laser field is evident, whereas this does not occur in pulsed operation. The high threshold of the cw IOPO of approximately 20 W is attributed to losses in the IOPO, especially in the AR-coatings of the PPLN and from absorption in the PPLN.

The dynamics of the IOPO was investigated using fast photodiodes monitoring the laser and signal output. The dynamic behaviour is very different from the dynamic behaviour of the laser itself. The relaxation oscillations of the laser occurs at approximately 90 kHz, while the relaxation oscillations of the IOPO occur in the MHz range. This behaviour which is due to coupling between the non-linear OPO equations and the laser equations is in good agreement with the theory of Turnbull et al.[3]

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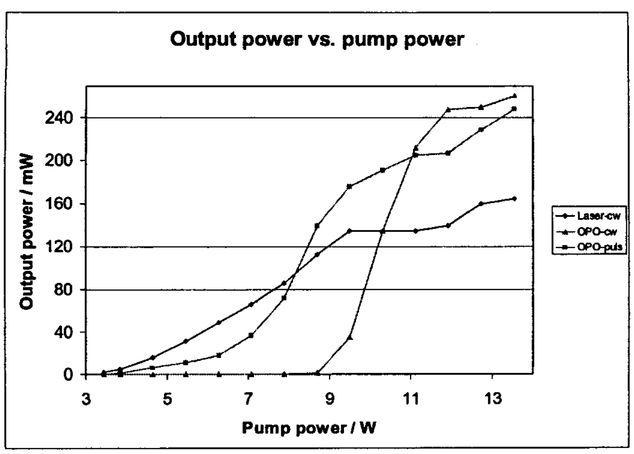

CThW5 Fig. 2. Output power from the IOPO in cw and pulsed operation.

CThW6 **6:00 pm**

Dual-cavity DROPO—An ideal single-mode source for non linear spectroscopy.

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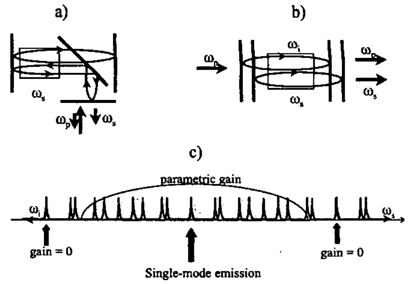
With the appearance of periodically poled crystals, tremendous developments were recently obtained in the field of continuous-wave (cw) optical parametric oscillators. However, the low power delivered by cw sources is not appropriate to address the problems of non linear spectroscopy and open air pollutant species detection. Pulsed OPOs seem to be a good alternative for such applications since high output power can be delivered over a large domain of wavelengths from rugged and compact devices. Nonetheless, the broad spectral bandwidth of nanosecond-duration pulsed OPO remains a serious drawback for spectroscopic purposes. Thereby alternatives were proposed to achieve single-mode output. On the one hand, single-mode output has been demonstrated by use of the injection seeding technique despite of a restricted tuning range of the OPO to the seeder source.[1] On the other hand, the insertion of filtering elements inside the cavity[2] provides single-mode operation but important losses are introduced, increasing dramatically the threshold of oscillation.

In this paper, we propose a new alternative, based on a dual-cavity doubly resonant OPO.[3] Figures 1a and 1b present two cavities that we tested in our lab. Figure 1c illustrates the principle of mode selection operated in these devices by use of a Giordmaine and Miller diagram : if a signal and an idler modes overlap perfectly, the energy conservation condition is fulfilled and those pairs of modes which are in exact coincidence are emitted. Practically, imperfect mode overlap can also lead to oscillation yielding to the well-known cluster behavior of single-cavity DROPOs. As we demonstrate here, using two separate cavities allows us to prevent oscillation with imperfect mode overlap. Hence, if only one exact coincidence lies within the gain bandwidth, the output will be single-mode. We thus capitalize on two advantages offered by the same double

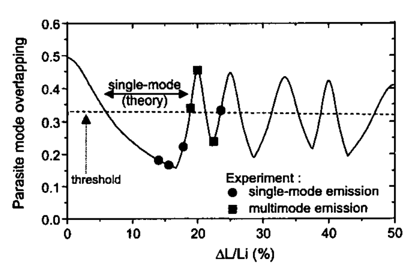


CThW6 Fig. 1. L-shaped cavity (a) and linear cavity (b) dual-cavity DROPOs. (c) principle of mode selection in dual-cavity DROPOs.

cavity design: low threshold thanks to the double resonance, single-mode output thanks to the double cavity.

Clearly, the spectral behavior of the DROPO depends on the value of the difference in length of the two cavities (ΔL). Hence, to predict the condition for single-mode operation, we calculate, for different ΔL values, the overlap integral I between all the signal and idler modes located in the gain bandwidth. This calculation is performed assuming that an exact coincidence is located in the center of the parametric gain bandwidth. If the threshold of oscillation is overcome, a parasite mode is emitted. Otherwise, the output is single-mode. Figure 2 illustrates the evolution of the maximum overlap integral as a function of ΔL/Li, where Li is the optical length of the idler cavity. The dashed line represents the threshold of oscillation. From this figure, it is seen that the mode overlapping remains below the threshold over five separated regions. For these regions, stable single-mode emission is expected. Figure 2 also presents experimental points. Dots correspond to ΔL/Li values for which stable single-mode output was obtained, and squares to ΔL/Li values for which the output was always multimode. The agreement between our model and experiment is quiet satisfactory.

Our model was also very useful to understand the role of the cavity finesse (the higher the finesse, the broader the single-mode regions). It is now used as a tool for designing new cavities. Experimental performances of two dual-cavity DROPOs will be presented: spectral linewidths (less than 300 MHz, see figure 3a), continuous tuning range (30 GHz), frequency



CThW6 Fig. 2. Overlap area as a function of the difference in length of the signal and idler cavities. Calculation corresponds to the L-shaped cavity OPO (gain bandwidth : 2.5 cm^{-1}; signal and idler cavity finesses are 50 and 7 respectively).