Contact Electrode Method for Bulk Periodically Poled $LiNbO_3$

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Over the past few years, there has been increasing interest in the use of quasi-phase-matched (QPM) nonlinear crystals, which permit noncritical-phase-matching for any wavelengths in the transparency range of the crystal, and have the advantage of using the largest component of the nonlinear susceptibility tensor, one that is not available in birefringent phase matching without walk-off problems[1],[2].

QPM can be achieved by an appropriate periodic modulation of the nonlinear coefficient, which corresponds to periodic domain reversal in ferroelectric materials. In particular, the application of QPM to bulk nonlinear optics has been revolutionised by the emergence of electric field poling techniques for patterning the domain structure of ferroelectric and polar crystals. In all the reported fabrication processes the periodic electrode (consisting of resist and/or metal layers) has been fabricated on the surface of the crystal substrates by conventional photolithography.

We report here a new fabrication process for PPLN - the contact electrode method (CEM) - in which the periodic electrode is pressed onto one of the substrate surfaces with a uniform electrode on the other. CEM does not need any photolithographic processes on the substrate surface which may lead to greatly reduced fabrication cost. Furthermore, CEM would be applicable for fabrications of periodically poled glass fiber [3].

Figure 1 shows the schematic experimental set up for CEM. The periodic electrode consists of a glass substrate of thickness of 110 μm, patterned with photo-resist of period of 6.58 μm covered in an Al contact layer (of dimensions 3mm x 1mm) of thickness of 0.2 μm. The resist thickness, the depth of periodic pattern, and the contact width were 3 μm, 1 μm, and 1.3 μm, respectively. The duty ratio of contact widths to the period was 20 %.

For the experiments we used a z-cut 0.3-mm-thickness $LiNbO_3$ substrate (12mm x 12mm) with optically polished on both z-faces. The samples were set between the contact electrode and the earth electrode as shown in Fig.1. The grating vector of the contact electrode was parallel to the x-axis of crystal. The -z surface of sample was earthed using a plane electrode and conductive gel. A pressure of 3.3 kg/cm^2 was applied to the back side of the "stamp" electrode. The Al contact electrode and the earth electrode were connected to the high voltage power supply and the ground potential, respectively.

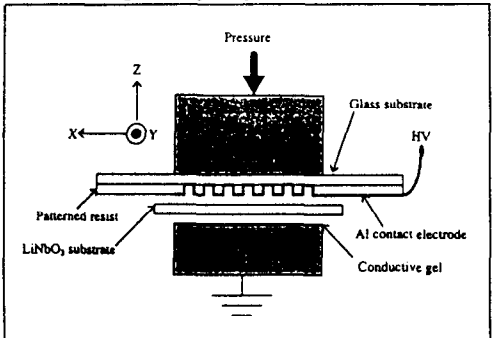

Fig.1 Schematic diagram of the experimental set up.

We used a programmed poling supply which controls the poling current and total charge. A voltage of approximately 7.2kV was needed to pole the samples with the supply operating in constant current mode.The current and the charge were 200 μA and 3.5 μC, respectively.

The samples were cut and polished for nonlinear optical characterisation by second

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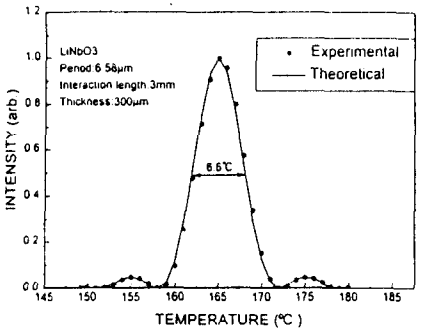

Fig. 2 Temperature dependence of second- harmonic power.

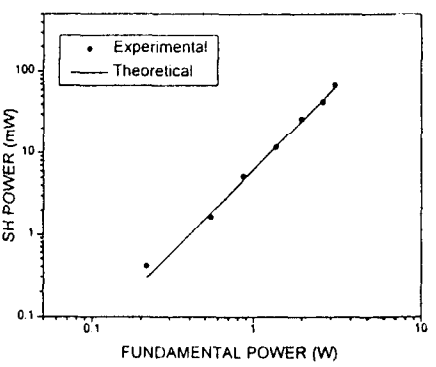

Fig. 3 Second-harmonic power as a function of the fundamental power.

harmonic generation using a cw Nd:YAG laser (1.064 μm) as the fundamental. The samples were set in an oven with the temperature controller. Figure 2 shows SH power as a function of temperature. It is in fairly good agreement with the theoretical prediction of 6.6 °C for the full width at half maximum. This correpondence means that uniform periodicity was achieved over the interaction region of 3 mm. The maximum SH power was obtained at 165 °C experimentally.

In the measurements of SH power, the focused spot size in the sample was 25 μm. Figure3 shows that the SH power as a function of the input fundamental power is close to the expected quadratic behavior over the full power range. These powers are internal values that take account of the Fresnel reflections at the input and output surfaces of the uncoated samples. As a result the maximum output power of 62.5 mW was obtained for an input fundamental power of 3.2 W in the PPLN.

From these measurements we have estimated the effective nonlinear coefficient d_{eff} of the PPLN sample. Analysis of the experimental results gave an effective nonlinear coefficient of 18 pm/V. This value is close to the theoretical limit of 22 pm/V expected for an ideal first-order QPM in PPLN. The theoeretical conversion efficiency using this d_{eff} is shown in figure 3 together with the experimental results. The slightly low nonlinear coefficient may be due to the variation in the duty ratio, and also to intrinsic properties such as variation of the crystal axis and crystal defects.

We have proposed and demonstrated a novel contact electrode method in which the periodic electrode is pressed onto one of the substrate surfaces and a high voltage applied. With this method bulk PPLN has been successfully fabricated with a period of 6.58 μm for frequency doubling a Nd:YAG fundamental wavelength of 1.064 μm over an interaction length of 3 mm using z-cut 0.3 mm-thickness $LiNbO_3$ substrates. The uniformity of the PPLN was verified from the dependence of SH power on the temperature, and 62.5 mW of green light was generated for an input fundamental power of 3.2 W. The contact electrode method should be applicable for large scale fabrication of periodically poled structures in nonlinear crystals such as $LiNbO_3$, and $LiTaO_3$.

We thank Prof. M. Esashi in the faculty of engineering in Tohoku University for the courtesy on the Tohoku University Venture Business Laboratory. We would like to acknowledge the help of Dr. Paul Routley and the micro-electronic fabrication facility at the University of Southampton for help with manufacturing photolithographic masks.

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