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1978

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CRYSTAL QUARTS AS AN INFRARED DICHROIC LASER MIRROR

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ABSTRACT

The use of α crystal quartz as a dichroic mirror for an optically pumped CO_2 laser is described. The 0.8 mm quartz plate provides high reflectivity (94% peak) in the 9.1 μ region and good transmission (70% average) for the 4-4.3 μm HBr pump laser.

(Submitted for publication in J.Phys.E: Sci.Instr.)

August, 1978.

1. INTRODUCTION

Optically pumped mid-infrared lasers have recently developed rapidly as a new, simple source of coherent radiation in the 7-25 μm wavelength region. These lasers are typically pumped by HBr, CO_2, doubled CO_2, DF or HF lasers (further possibilities being HCl, DCl, etc.) and they require an optical system providing input coupling for the short wave pump and a suitable cavity for the longer wavelength output.

In many systems an off-axis pumping geometry has been used (J.M. Green and H.N. Rutt, 1977, for example). However, on-axis pumping via a dichroic mirror offers a number of advantages: simplicity of the optical system, improved pump uniformity and ease of alignment. Multi-layer dichroic mirrors have been used for this purpose (H. Kildal and T.F. Deutsch, 1976, T.Y. Chang and O.R. Wood, 1977) but suffer from a number of disadvantages including high cost, limited availability, low damage threshold, and are usually opaque to visible radiation making alignment difficult.

The use of natural reststrahlen reflection of ionic crystals as a dichroic mirror for use in far infrared lasers (30-100 μm) has previously been suggested by M.R. Green et al, 1978. However the technique has not been previously demonstrated at any wavelength.

2. PROPERTIES OF CRYSTAL QUARTZ

We have chosen to demonstrate the utility of this technique using α-quartz. This material is readily available in high quality plates of sub-mm thickness, since such plates form a standard component in dye-laser birefringement tuning filters. The plate used was 0.8 mm thick and the optic axis was contained in the plane of the plate. The infra-red reflection of crystal quartz has been previously investigated in detail (K. Sato 1965, W.G. Spitzer and D.A. Kleinman 1961) and for particular orientations the reflectivity can approach 100% at 9.1 μm. The reflection and transmission of the standard as-purchased plate in nomi-

nally unpolarized light is shown in Fig.1, and the reflectivity reaches a peak of 94% at 9.1 μm. The sample has an averaged transmission of 70% in the 4.0-4.2 μm HBr laser region, and was undamaged by exposure to 1,000 pulses at 1.5 J/cm^2 of HBr laser radiation. These characteristics compare very favourably with multi-layer dichroics.

3. EXPERIMENTAL RESULTS

A simple in-line cavity, Fig.2, comprising the flat crystal quartz plate and a 5 metre radius metal mirror with a 1 mm coupling hole was used to test the system. The gas cell was of all PTFE and glass construction with Brewster's angle KBr windows. A 50:50 mixture of HBr:CO_2 was pumped by up to 200 mJ of multi-line HBr laser radiation, of which ~ 80 mJ was in the 1-0 HBr laser band. The output was detected with a calibrated pyroelectric energy meter, using an InSb filter to reject the pump radiation.

The system was operated with $C^{12}O_2^{16}$ and $C^{12}O_2^{18}$ and, in both cases, operated reliably over a wide pressure range, ≤ 10 Pa to 2000 Pa. A maximum output of 2 mJ was obtained from $C^{12}O_2^{18}$, outputs from $C^{12}O_2^{16}$ were approximately a factor of ten smaller. The optimum operating pressure was 100-200 Pa for both isotopes. The wavelength of the reststrahlen maximum in α-quartz forces operation of the $C^{12}O_2^{16}$ on the R branch of the 001-02^{0}0 transition at high J, whereas for $C^{12}O_2^{18}$ the reststrahlen band is a good match to the room temperature thermal peak of the R branch of the 001-02^{0}0 band (R. Beck et al, 1978). This difference explains the improved performance with $C^{12}O_2^{18}$.

Laser action was delayed by 800 ns from the pump pulse, and consisted of a 200 ns spike followed by a 2.5 μs tail.

The high optical quality and transparency in the visible region of the crystal quartz makes this system exceptionally easy to align. Optimum output was always generated at the nominally aligned condition as determined with a HeNe laser, and no improvements could be obtained by adjustments with the system operating. No damage was observed on the quartz flat even after prolonged operation.

4. CONCLUSIONS

We have demonstrated the utility of the reststrahlen reflectivity of α-quartz as a dichroic laser mirror for the 8.3-9.4 μm region. A number of other materials (LiF, MgO, Al_2O_3, MgF_2, SiC, GaP for example) show strong reststrahlen bands in the 7-25 μm region, and will be of use with other optically pumped lasers.

Although limited in the wavelengths at which high reflectivities are available, the simplicity, high optical quality, low cost and transparency in the visible region of the spectrum make these natural dichroics a useful alternative to multi-layer filters.

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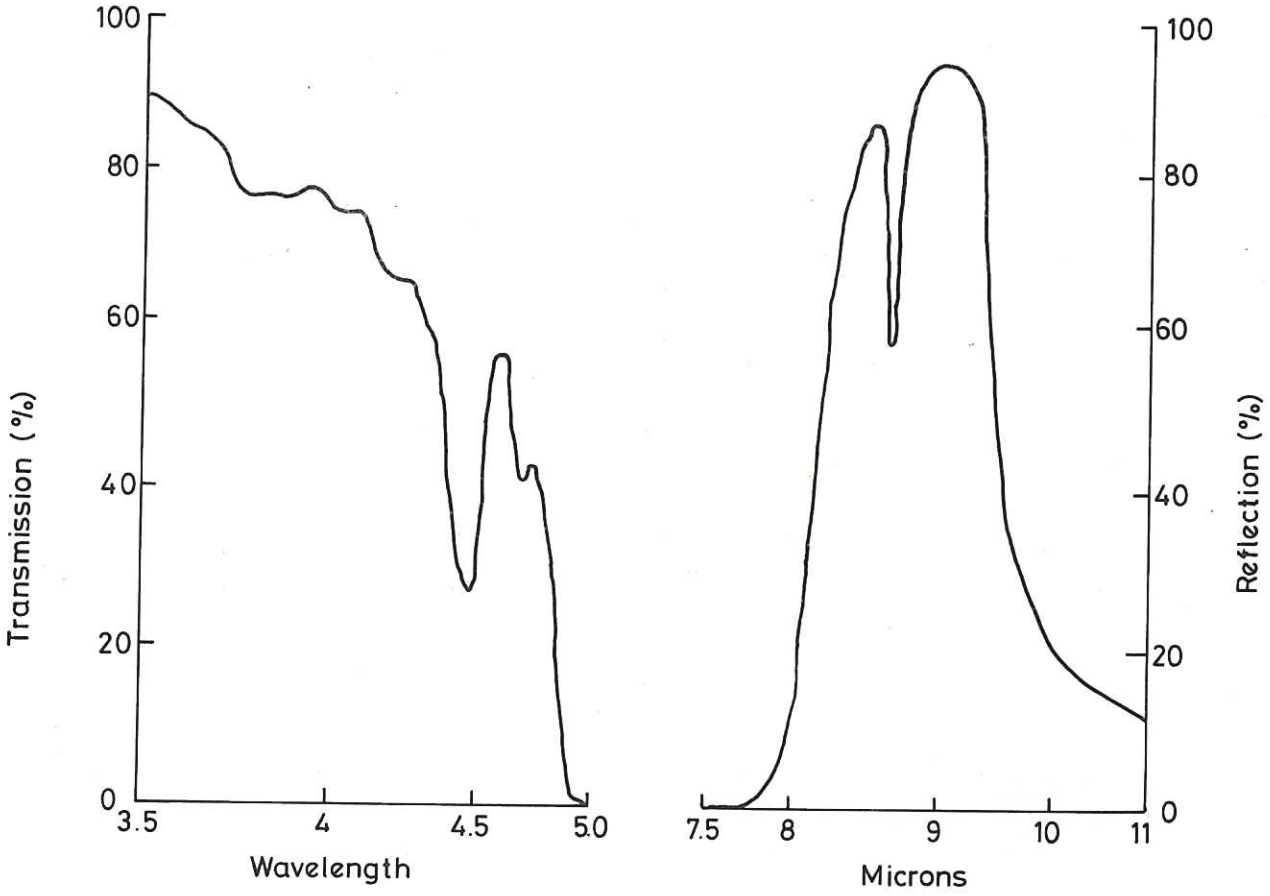

Fig.1 Transmission and reflection of the 0·8mm crystal quartz plate.

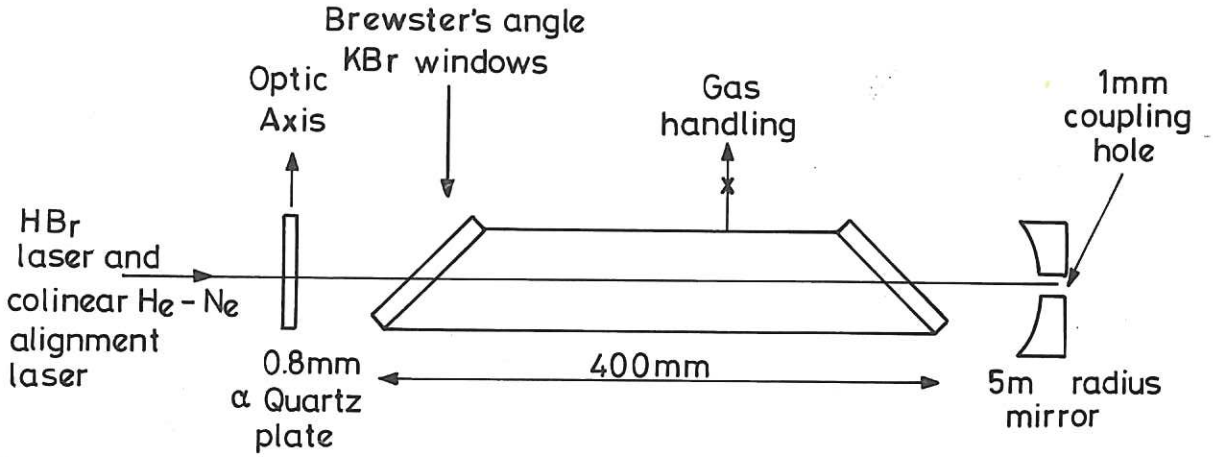

Fig.2 Optical pumping system.