COLOR CENTER LASERS FOR HIGH RESOLUTION SPECTROSCOPY

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Abstract

Recent developments of stable color center crystals have provided new possibilities for tunable cw lasers in the 1 to 4 μm region. Design considerations for computer-controlled high resolution and high sensitivity infrared laser spectrometers will be presented.

Introduction

Color center lasers capable of high power, single frequency operation and broad wavelength tunability offer new prospects for linear and nonlinear spectroscopy of atoms and molecules in the near infrared [1,2,3]. In this paper design considerations and operation of continuous wave color center laser spectrometers will be described, and a number of spectroscopic applications of the color center laser will be discussed, specifically high sensitivity and high resolution absorption spectroscopy of free radicals [4] and optical pumping experiments of metastable He atoms [5]. In the discussion of spectrometer design, special emphasis will be given to computer control and data acquisition which have been demonstrated to greatly facilitate high resolution spectroscopic measurements from the viewpoint of long range survey and single frequency scans, wavelength and frequency calibration and convenient data acquisition. Both linear and ring cavity configurations have been used for spectrometers, and spectrometer designs based upon both kinds of cavities will be described.

Several new techniques for obtaining high resolution near infrared spectra have been developed in the last ten years. These include cw tunable laser sources, such as color center lasers, diode lasers, spin flip Raman lasers, frequency difference mixing techniques, as well as significant improvements in Fourier transform spectrometers. The important characteristics of a spectrometer are resolution, range of wavelength coverage, sensitivity, cost and versatility. For spectrometers based upon laser sources, high resolution requires good frequency stability and purity and high sensitivity requires good amplitude stability and reasonably high output power. Output power is of crucial importance to all nonlinear spectroscopic techniques. Table 1 lists a comparison of these qualities for the cw infrared spectrometers of current interest.

Table 1
Comparison of Infrared Spectroscopic Instruments

	CCL	FTIR	Diode Laser	Frequency Difference	IR Grating Spectrometer
Resol. (cm^{-1})	0.0001	0.05-0.002	0.0001	0.0001	1.0-0.05
Source Type	coherent	incoherent	coherent	incoherent	coherent
Range (μm)	0.8-3.6	0.5-100.0	1.0-12.0	1.0-5.0	1.0-10.0
Divergence	1-2 mRad	N.A.	>10 Deg	1-5 mRad	N.A.
Output Power	1-500 mW	N.A.	1-100 μW	1-100 μW	N.A.
Source Noise	high	low	low	high	low
Cost	high	v. high	high	high	moderate

The results of comparison of color center lasers with the other techniques can be briefly summarized. Although color center lasers have the disadvantages of being more limited in spectral range compared to the other listed techniques and noisier than laser diodes, they possess most of the desirable characteristics for high resolution spectroscopy in the near infrared. For spectroscopic techniques requiring tunable, high power, single frequency coherent radiation such as double resonance and saturation spectroscopy, color center lasers are currently not only the optimal but essentially the only choice.

With regard to future development of new sources, it should be pointed out that cw laser operation has been recently demonstrated in several divalent transition-metal-doped crystals with tunability from 1.5 to 2.3 μm for Ni:MgF_2 and Co:MF_2 [6]. However, to date these laser materials are not commercially available.

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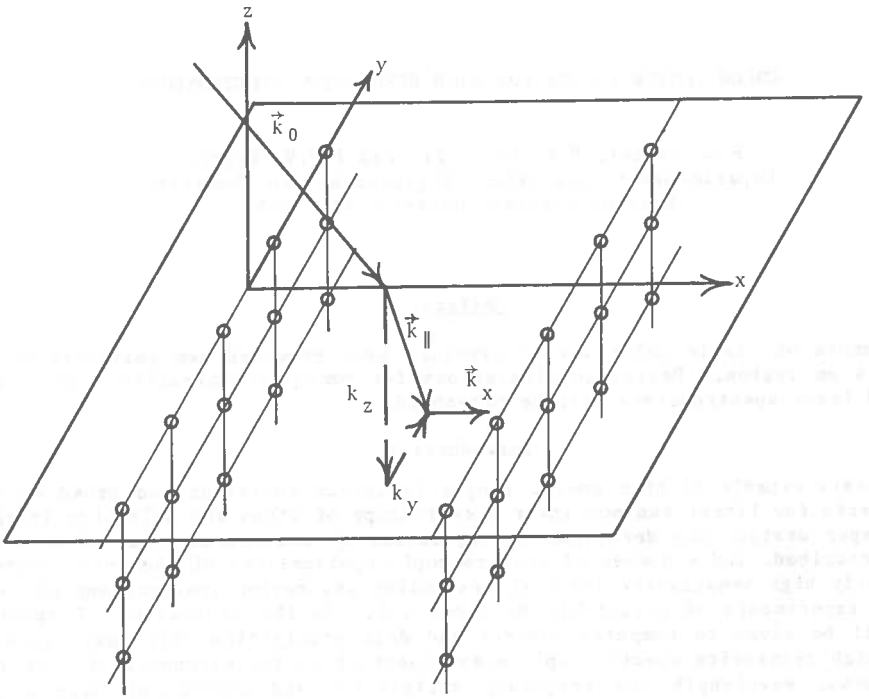

Fig. 1. The systematic reflections geometry. The projections of the momentum $\hbar\vec{k}_0$ of the incident particle on the crystal axes are shown.

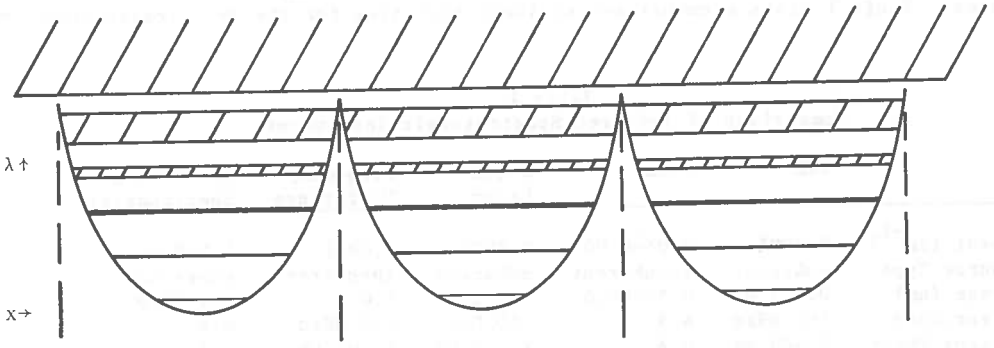

Fig. 2. Band structure pertaining to a positive particle in the transverse potential of the systematic reflections geometry (single potential minimum case). Dashed lines indicate positions of atomic planes. Shaded areas are allowed bands.