

Room-Temperature Color Center Lasers

TASOLTAN T. BASIEV, SERGEI B. MIROV, AND VYACHESLAV V. OSIKO

(Invited Paper)

Abstract—A survey of results is presented on the development of room temperature tunable lasers using color centers in ionic crystals and on using color center crystals as nonlinear filters and passive Q-switches for neodymium lasers.

I. INTRODUCTION

LASERS using color centers (CC's) in ionic crystals, developed over the last 10 years, have become a new class of sources of coherent radiation with smoothly tunable wavelengths [1]–[12]. They possess an array of unique characteristics, such as 1) the practically important wavelength tuning region ranging from 0.5 to 4 μm , 2) high wavelength stability, and 3) an extremely narrow output spectral width, achievable virtually without power loss while preserving a continuous wide region of tuning (up to 2500 cm^{-1}) due to quasi-homogeneous broadening of their gain transitions.

The superb characteristics obtained by available and simple laser techniques, and the capability of color-center lasers (CCL's) to operate efficiently in all the known temporal modes (continuous to subpicosecond pulse) make them most promising tools for experimental physics. They confidently compete with semiconductor lasers, notable for their high resolution in the near IR region, and essentially surpass them in peak and average power, low radiation divergence, and region of continuous wavelength tuning. Color-center lasers also do not yield to parametric light oscillators in output power in nano- and picosecond operating modes and surpass them in quasi-continuous and CW regimes. Due to their high gain, the CCL features a considerably narrower oscillation spectrum, as well as a low sensitivity to the quality of the cavity optical elements and to the spatial-angular and spectral characteristics of the pump radiation.

The aim of this paper is to give a review of the present status of research in the field of development and application of room temperature CCL's.

The idea of making lasers using electron-vibrational transitions of color centers was first discussed as far back as 1961, soon after the first laser was demonstrated. B. Fritz and E. Menke [13] were the first in 1965 to attain oscillation with a color center using a pulsed flashlamp to pump a KCL-Li crystal with $F_2(\text{H})$ centers, cooled to

liquid nitrogen temperature. In the following decade, CCL's virtually fell outside active research interests. Considerable effort was devoted during this period to the development of tunable lasers using solutions of organic dyes. The availability of dyes, and the simplicity of creating an active volume, prompted a wide range of tunable dye laser research efforts. However, as early as the mid-1970's, when new application opportunities and requirements arose, and the merits and shortcomings of the dye lasers were clearly determined, an interest in tunable CCL's was renewed. Also by that time, the major techniques for narrowing laser radiation and for wavelength tuning across broad-electron-vibrational amplification bands using different types of dispersive cavities had been elaborated.

One of the first among those returning to the problem of making CCL's was a Bell Telephone group (U.S.A.). In 1974 they demonstrated [1], [6], [12] high monochromaticity and a wide tuning range of a KCL-Li laser with an $F_2(\text{H})$ CC, operating at nitrogen temperature (77 K) and laser pumped [14], [15]. This group [1], [6], [12] engaged in a search for new CCL media and the achievement of different operating modes of cryogenic CCL's.

Later on, another group [16]–[18] from the Institute of Thermo-Physics of the U.S.S.R. Academy of Sciences achieved room temperature oscillation on new quasi-molecular aggregate CC (F_2^- , F_2^+ , and F_2^0) in LiF and NaF crystals and showed them to be promising for producing tunable radiation in the spectral range 0.7–1.4 μm .

A group [19], [20] from the Hannover Technological University (West Germany) was the first to make a cryogenic ($T = 77$ K) $F_2(\text{H})$ CCL. They developed the techniques for attaining super stable narrow-band CC oscillation.

Scientists from the Irkutsk State University (U.S.S.R.) proposed the technique of optical stabilization of thermally unstable F_2^+ centers by doping the crystals with different impurities, and obtained oscillation using these impurity-vacancy centers at room temperature [2], [21], [22].

Oscillation on impurity-vacancy (F_2)₄ CC's in Na-doped CaF and SrF₂ was attained at $T = 300$ K by researchers [23], [24] at the State Optical Institute (U.S.S.R.).

Scientists [25]–[29] of the General Physics Institute of the U.S.S.R. Academy of Sciences proposed new schemes for attaining tunable radiation using thermo- and photo-unstable CC's at room temperature, developed the tech-

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The authors are with the General Physics Institute, U.S.S.R. Academy of Sciences, Vavilov str. 38, Moscow 117942, U.S.S.R.
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