1.2.4 Color Center Laser

When crystals of Alkali Halides are exposed to high energy radiation such as x-rays or electrons, point defects are created within the crystal. These point defects add more energy levels to the atoms in the crystal (similar to impurity energy levels in semiconductors). These extra energy levels can cause optical absorption at specific wavelengths, thus adding color to the transparent Alkali Halides. These colors gave the name color center lasers to these lasers.

There are few kinds of defects in crystals, but for our purpose we shall explain the simple defect called F-center (from the German word "Farbe" for color). Without giving specific details about energy levels in crystals, it is enough to describe the defect in the crystal as causing local region with extra positive charge. This region can be regarded as a "nucleus" around which electrons can be assembled similar to Hydrogen atom. The electron is bound to a positive Halogen vacancy. The excited electron energy states in the lattice are strongly coupled to lattice vibrations. Thus, all electronic states are broadband, resulting in broad absorption and emission bands.

The differences between the energy levels of color center and the Hydrogen atom are:

- The energy levels of the color center are wide and occupy bands, because of the interaction between neighboring atoms - crystal vibrations.
- Absorption band are not the same as emission bands, as can be seen in figure 1.18.

Figure 1.18: Absorption and Emission Spectrum Bands of F Center in KCl
Tunable color center lasers in Alkali Halide crystals can in principle cover the spectrum range from 0.6 - 4 µm. However, there are problems with shelf life of these lasers and with their stability during operation.

Color center lasers operate at liquid Nitrogen temperature (77 °K). The main advantage of color center laser is its single frequency purity. In single mode continuous wave operation, linewidth below 4 KHz have been achieved.

**Summary of Color Center Laser according to Groups:**

- Solid state laser.
- Optically pumped usually by another laser (which emit in the absorption spectrum of the color center). Since the energy levels are not discrete but bands, it is a tunable laser, and the emitted wavelength can be controlled.

**Applications of Color Center Lasers:**

- Basic research: Spectroscopy of atoms and molecules (because of the narrow bandwidth of the emitted wavelength, and the broad range of tunability).
- Laser chemistry - to initiate chemical reaction by selective excitation of specific levels of atoms and molecules.