We report FIR laser spectroscopy study of Zn$_{1-x}$Fe$_x$Se ($x < 0.06$) Semimagnetic Semiconductor at the temperature range of 2–26 K and magnetic fields up to 18 T.

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One of the central problems of Fe-based Semimagnetic Semiconductor (SMSC) is the information about the energy structure of the Fe$^{++}$ ion ground term ($^5E$, split into a singlet $A_1$, a triplet $T_1$, a doublet $E$, a triplet $T_2$ and a singlet $A_2$ [1]). A useful tool to study this structure is far infrared (FIR) spectroscopy [1, 2]. Recently, an investigation of Fe-type SMSC has been reported [3, 4], however it dealt with rather low Fe concentrations. In this paper we present complementary results of FIR laser spectroscopy for Zn$_{1-x}$Fe$_x$Se ($x < 0.06$) in the temperature range 2 < $T$ < 26 K and magnetic fields up to 18 T.

In Fig. 1 we display resonant energies observed experimentally as a function of magnetic field. The previously observed [3, 4] transitions $A_1 - T_1$ and $A_1 - E$ are clearly visible also for higher $x$, although the spectra are broader than those obtained for low $x$. The experimental energies match well the calculated energy level differences for isolated, i.e. not interacting Fe$^{++}$ ion (Fig. 1). We notice that the line observed at 14.3 cm$^{-1}$ coincides with the lowest transition $A_1 - T_1$. However, this transition is only weakly dependent on the field and therefore should not be observed in laser spectroscopy as a resonance (fixed energy of laser line). In that respect the origin of 14.3 cm$^{-1}$ line is still not clear.
For Zn$_{0.94}$Fe$_{0.06}$Se we observed a weak and broad line at 8.2 cm$^{-1}$ (Fig. 1). This line disappears at temperatures $T > 5$ K and is not visible for lower Fe concentrations. We stress that the transition energy is roughly two times smaller than the lowest transition energy expected for isolated Fe ion. A possible candidate for the 8.2 cm$^{-1}$ lines is the transition between the ground and the first excited states of a Fe–Fe pair coupled by exchange interaction. In ZnFeSe, calculated energy of this transition is about 8–9 cm$^{-1}$ [5]. An increasing contribution of pair and larger clusters to FIR absorption should be expected for $x > 0.03$ and is indeed exhibited by the changes of FIR absorption spectra shape [6, 3] as well as by the temperature variation of the spectra (Fig. 2). We believe, however, that the available data are too preliminary to establish the nature of 8.2 cm$^{-1}$ line.
Fig. 2. The experimental FIR transmission spectra of Zn$_{0.94}$Fe$_{0.06}$Se as a function of magnetic field for various temperatures. The laser energy was 21.2 cm$^{-1}$. Curves at $9 < T < 26$ K show results for upward and downward sweeps of magnetic field.

References