Excitation-emission spectroscopy of Nd$^{3+}$ ions after ferroelectric domain inversion by direct electron beam writing in LiNbO$_3$:Nd$^{3+}$ crystals

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The possibility of using the quasi-phase matching (QPM) technique for efficient multi-frequency conversion by periodically altering the orientation of the ferroelectric axis using Nd$^{3+}$ or Yb$^{3+}$ activated crystals has given place to a number of different techniques in order to fabricate 1D and 2D periodically inverted structures in LiNbO$_3$.

In this work we have used direct electron beam irradiation onto Nd$^{3+}$ doped LiNbO$_3$ single domain crystals to produce polarization domain inversion in the micrometer range. The irradiation has been performed by using a scanning electron microscope.

In order to study the effect of the polarization inversion by the electron beam writing in the optical transitions of Nd$^{3+}$ ions, total site selective (emission and excitation) spectroscopy with spatial resolution in the micrometer range has been used at low temperature (10K).

Total site selective spectroscopy allows to obtain the splitting and barycentre of the $^4F_{3/2}$ state for each one of the different non-equivalent Nd$^{3+}$ centres appearing in the original and inverted domains. The results show the presence of similar Nd$^{3+}$ centres for both inverted and non inverted zones. However, when comparing the original and the inverted domains regions, slight differences in the amount of the crystal field splitting of the $^4F_{3/2}$ state of Nd$^{3+}$ ions have been observed, being this splitting higher in the polarization inverted domain regions. In the other hand the barycentre is practically the same for the three Nd$^{3+}$ centres in the original region and shows a slight increase in the inverted domain. This difference between inverted and original non-equivalent optical centres of Nd$^{3+}$ is attributed to the strong ion-lattice re-accommodation that is taking place during the poling process.

In our work, the effect of the charge density used during the domain inversion process is also analyzed.