EPJ Web of Conferences **161**, 03019 (2017) DOI: 10.1051/epjconf/201716103019
PECS-2017

Stationary and coherent spectroscopy of $^{167}Er^{3+}$ in waveguides in $^{7}LiYF_4$ crystal

Mansur Minnegaliev[1], *Ravil* Urmancheev[1,*], *Konstantin* Gerasimov[1], *Alexander* Kalinkin[2], *Ivan* Dyakonov[2], *Mikhail* Saygin[2], *Sergey* Kulik[2], *and Sergey* Moiseev[1]

[1]Kazan Quantum Center, Kazan National Research Technical University n.a. A.N. Tupolev-KAI, 18a Chetaeva Str., Kazan, 420126 Russia
[2]M.V. Lomonosov Moscow State University, Faculty of Physics, Leninskie Gory, Moscow, 119991 Russia.

Abstract. We have conducted a spectroscopic investigation of $^{167}Er^{3+}$ ions in optical waveguides on an optical transition between the hyperfine sublevels of $^4I_{15/2}$ and $^4I_{9/2}$ multiplets. Waveguides with diameters ranging from 20 to 100 μm were produced in the crystal by a femtosecond laser using the depressed-cladding approach. The spectroscopy results of $^{167}Er^{3+}$ ions inside the waveguides show additional broadening and an overall shifts of the spectra compared to the bulk spectrum of ions. The sign of the observed frequency shift depends on the diameter of the specific waveguide. We have also observed a two-pulse photon echo in several waveguides. The acquired results show the possibility for integrated quantum schemes in rare-earth ions doped crystals.

Development of optical quantum technologies including optical processors and quantum repeaters is accompanied by the increased attention to their subsequent realization in optical integral schemes. That means that experimental development of integral quantum memories in such schemes is also necessary. Multi-atomic systems can serve as active media for such experiments, such systems include crystals that often have longer quantum coherence times. So waveguides in crystals doped with rare-earth ions are of great interest especially those combinations of rare-earth ion and crystal matrix that exhibit desirable spectroscopic parameters for quantum memory realization. In our previous work we studied the $^{167}Er^{3+}$:$^{7}LiYF_4$ crystal [1], where we observed a 90 MHz inhomogeneous linewidth for the optical $^4I_{15/2}(\Gamma_{56}) - {}^4I_{9/2}(\Gamma_{78})$ transition. Then, thanks to the advances in the crystal growth techniques this value was lowered down to 24 MHz [2]. Such narrow inhomogeneous linewidth of optical transition makes this crystal a promising candidate for Raman quantum memory realization.

In this work we present the results of spectroscopic study of $^{167}Er^{3+}$ ions in symmetrical waveguides in $^{7}LiYF_4$: $^{167}Er^{3+}$ crystal. Five 15.8 mm long waveguides with diameters of 20, 30, 50, 75 and 100 μm and were produced by a femtosecond laser using the depressed-cladding approach with 515 nm wavelength. We carried out a high-resolution spectroscopy of $^{167}Er^{3+}$ ions in different waveguides at 4 K temperature. Fig. 1a shows three of the resulting

* Corresponding author: ravil@kazanqc.org

spectra in π polarization, for 30, 100 μm waveguides and for the bulk of the crystal. The absorption lines of ions inside the waveguide are broadened due to additional inhomogeneities introduced by the local tensions caused by the waveguide creation process. The optical density falls subsequently since the atomic absorption lines are spread ever the wider area. Fig. 1a also shows that the spectra obtained in the waveguides are also shifted from the central frequency defined by the bulk spectrum. For 100, 75 μm waveguides $^{167}Er^{3+}$ spectra are shifted to the lower frequency region, for 50 μm waveguide the spectrum (not shown on the figure) stays in the center and 30 and 20 μm waveguide spectra experience the opposite sign shift to higher frequencies.

We have also investigated the system by coherent spectroscopy techniques. It is worth noting that despite the absorption lines widening we managed to observe two-pulse photon echo in some of the waveguides (see fig. 1b). At the same time for the crystal studied in [1] with 90 MHz inhomogeneous linewidths we could not see the echo. The photon echo experiments were conducted on the single absorption line that is located around the zero frequency on fig. 1b. The first obtained estimations reveal that the transverse relaxation time for this transition is at least 500 ns. The obtained results show that quantum integrated schemes are possible to realize in the studied $^{7}LiYF_4$: $^{167}Er^{3+}$ crystal.

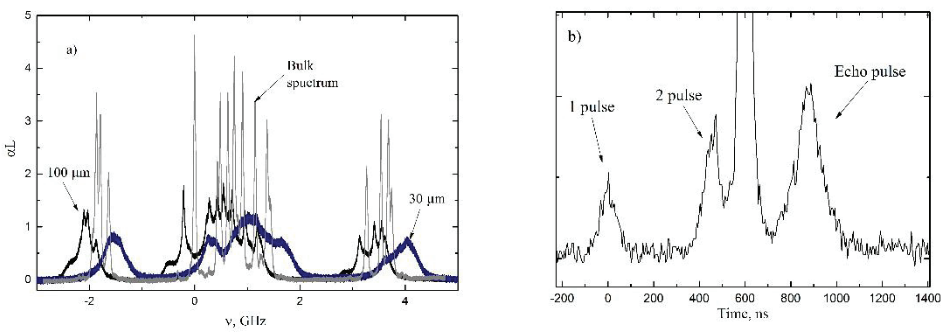

Fig. 1. a) $^{167}Er^{3+}$ ions absorption spectra in $^{7}LiYF_4$ crystal in bulk (light gray curve), in 100 μm diameter waveguide and in 30 μm diameter waveguide (two black curves). Zero on the frequency scale corresponds to the ν=370,574 THz. b) Two-pulse photon echo signal for 100 μm waveguide. The delay between the first two pulses equals 450 ns.

This work is supported by Russian Foundation for Basic Research grant #17-02-00918.

References

[1] K.I. Gerasimov, M.M. Minnegaliev, B.Z. Malkin, E.I. Baibekov, S.A. Moiseev, Phys. Rev. B **94**, 054429 (2016)

[2] M.M. Minnegaliev, E.I. Baibekov, K.I. Gerasimov, S.A. Moiseev, M.A. Smirnov, R.V. Urmancheev, Quant. Electron. **47**(9), 778 (2017)