Acoustically Induced Transparency for Gamma-Ray and X-Ray Photons

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The induced transparency of opaque medium for resonant electromagnetic radiation is a powerful tool for manipulating the properties of both the field and atomic ensembles in a wide spectral range of radiation from microwaves to X-rays and various physical conditions. In this presentation, we discuss a technique that allows one to make the medium with Fe-57 nuclei transparent for resonant photons with an energy of 14.4 keV at room temperature. The technique is based on the acoustic vibration of the absorber with ultrasonic frequency along the direction of the photon propagation. The 14.4 keV photons can be emitted by a radioactive Mossbauer source Co-57 (RMS) [1] or by a Synchrotron Mossbauer source (SMS) [2,3]. Such an Acoustically Induced Transparency (AIT) of the stainless-steel foil with a natural abundance of Fe-57 nuclei was observed recently for resonant 14.4-keV gamma-ray photons from the RMS Co-57 [1]. About 150-fold suppression of the resonant absorption with the possibility to preserve the spectral and temporal properties of the 14.4-keV photons was demonstrated. However, the conditions of the experiment did not allow locking the phase of the absorber vibration to the front of the incident single-photon wave packet. We have shown that using RMS to obtain such phase-locked AIT is inefficient. At the same time, the use of SMS instead of RMS offers several efficient regimes of phase-locked AIT for 14.4-keV X-ray photons based on the possibility to control the phase of the absorber vibration relative to the front of the SMS single-photon wave packet [4]. We have shown that in the phase-locked AIT, the interference effects appear during the photon propagation through the absorber. They may cause an alteration of the spectral and temporal properties of the transmitted single-photon wave packet, which is controlled by the initial phase of the absorber vibration.

We show that the AIT for RMS gamma-ray photons and SMS X-ray photons is somewhat similar to the Electromagnetically Induced Transparency and Autler–Townes effect in optics. In particular, the 14.4-keV photons can be slowed down below 10 m/s at room temperature at Fe-57 absorbing medium at room temperature. In such a way, the proposed technique of AIT can become a component of the acoustically controllable interface between X-ray/γ-ray photons and nuclear ensembles.

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References

[1] Y V Radeonychev, I R Khairulin, F G Vagizov, M Scully and O Kocharovskaya, Phys. Rev. Lett. **124**, 163602 (2020)

[2] V Potapkin, A I Chumakov, G V Smirnov, R Ruffer, C McCammon and L Dubrovinsky, Phys. Rev. A **86**, 053808 (2012)

[3] T Mitsui, R Masuda, M Seto and N Hirao, J. Phys. Soc. Jpn. **87**, 093001 (2018)

[4] I R Khairulin, Y V Radeonychev, V A Antonov and O Kocharovskaya, Sci. Rep. **11**, 7930 (2021)