Nuclear ensembles with controllable inhomogeneous broadening for nuclear quantum memories and spectral intensity enhancement

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Record high resonance quality factor can be achieved in nuclear ensembles at room temperature solids such as Q 1013 at 14.4keV transition in 57Fe or 1019 at 12.4keV transition in 45Sc. These numbers are unmatchable with optical transitions in room temperature solids. The hard x-ray photons with corresponding 10 keV energies also have some advantages compared to optical photons. For example, 14.4-keV radiation can be focused into a several nanometers diameter spot and resonantly absorbed by just 70 nm-thick 57Fe foil. The efficiency of the single photon detectors is also higher in that range of photon energies. These appealing features stimulate the development of quantum nucleonics/quantum x-ray optics (see for example [1-3] and the references there in). However, interfacing a single photon with a nuclear ensemble is challenging due to the absence of the relatively bright spectrally narrow hard x-ray radiation sources as well as high quality cavities. In this talk we discuss a possibility to use a controllable inhomogeneous broadening in order to store an incident spectrally broad single photon in the nuclear ensemble and at a later time either to retrieve it on demand (similar to an optical quantum memory via gradient echo or atomic frequency comb protocols [4,5]) or to squeeze it in a spectral domain in order to achieve higher spectral intensity [6], required for addressing of the ultra-narrow nuclear resonances. We show that such controllable inhomogeneous broadening at the x-ray nuclear transitions can be realized i) via introducing a transition frequency gradient in a nuclear ensemble along the photon propagation direction, or ii) via a set of the resonant nuclear absorbers moved with different velocities (nuclear frequency comb) [3]. Finally, we will discuss the recent experimental demonstration at DESY of the nuclear quantum memory via nuclear frequency comb [7], as well as our plans for demonstration of the resonant addressing of the ultra-narrow (1.4 femto-eV natural linewidth) nuclear transition at 12.4 keV in 45Sc to be performed this fall at the European XFEL.

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