Compression of The X-Ray Photon Waveform from the Synchrotron Mössbauer Source into a Short Pulse in an Oscillating Resonant Absorber

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Generation of coherent radiation in the form of a single pulse or a given number of pulses is an important problem for all ranges of the electromagnetic spectrum. Different applications require a different number of pulses in a sequence and a certain pulse length.

In the X-ray range, radiation pulses with the photon energy of 14.4 keV find a lot of applications in Mössbauer spectroscopy and X-ray quantum optics. The main sources of this radiation are the radioactive ^{57}Co Mössbauer source and synchrotron radiation sources after a proper narrowing of the extremely broadband X-ray bursts emitted from the storage ring. There is also a synchrotron Mössbauer source (SMS) of 14.4 keV radiation available at the European Synchrotron Radiation Facility (ESRF) and Spring-8 facility [1,2]. It constitutes a near-perfect $^{57}FeBO_3$ (iron borate) single crystal which can transform the X-ray bursts into single 14.4-keV photons with spectral-temporal characteristics similar to photons from the ^{57}Co source [1]. The SMS can produce single-photon pulses with different waveforms (time dependence of the photon detection probability or, equivalently, the intensity of the single-photon wave packet) and duration. Their main feature is a smooth front edge in contrast to the stepwise front edge of the photon waveform emitted by radioactive Mössbauer sources. As a result, the waveform of the SMS photon transmitted through a resonant medium does not contain the Sommerfeld-Brillouin precursor (part of the photon waveform near the front edge, which weakly interacts with nuclei and, hence, is almost unchanged by the medium). This opens up the possibility of compressing the SMS photon waveform into a single short, high-intensity pulse, which cannot be realized with the single-photon pulse from radioactive sources.

Based on this, we propose the experimental conditions for the implementation of compression of a 100 ns length 14.4-keV single-photon wave packet produced by SMS at the ESRF to a single bell-shaped nearly bandwidth-limited pulse of 20 ns duration and more than twice the peak intensity. On-demand, this single-photon wave packet can also be transformed into an arbitrary number of nearly bandwidth-limited, ultrashort pulses up to picosecond duration. This compression is based on the transmission of SMS photons through a piston-like vibrated stainless-steel foil enriched with ^{57}Fe nuclide. Such compressed single-photon coherent pulses and single-photons shaped into pulse sequences are promising for applications in X-ray quantum optics, including the implementation of quantum memory and quantum gates.

References

[1] V Potapkin, A I Chumakov, G V Smirnov, J-P Celse, R Rüffer, C McCammonb and L Dubrovinsky, J. Synchrotron Radiat. **19**, 559 (2012)

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