New time-domain spectroscopic methods at Novosibirsk FEL

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Abstract— Powerful coherent pulse-periodical radiation of the terahertz Novosibirsk free-electron laser (NovoFEL) allows to carry out unique experiments in the field of time-domain spectroscopy. Different spectroscopic methods from ultrafast (measuring time − 200 ps, resolution - $2\cdot10^{-3}$) to super-high unlimited resolution are presented in the report.

Keywords— free-electron laser, terahertz radiation, time-domain spectroscopy, molecular free induction decay radiation, heterodyne spectroscopy, ultrafast single-pulse spectroscopy, super-high-resolution spectroscopy, magnetic spectroscopy, non-Faraday rotation of polarization, comb-spectroscopy

I. ULTRAFAST SINGLE-PULSE SPECTROSCOPY

Ultrafast single-pulse spectroscopy based on polarized heterodyne spectrometer [1] allows extending of spectroscopic measurements in the field of unrepeatable unstable or principal single phenomena. Using this method we measured spectra of separate NovoFEL pulses in resonance regime with maximal output power when side-band instability of radiation took place [2]. It should be noted that other fast sampling technologies like to usual time-domain spectroscopy of Fourier-spectroscopy did not work in the case. The method can be applied, for example, to study of explosion processes.

II. TIME-DOMAIN GAS DYNAMIC SPECTROSCOPY

Beating signal of free induction decay (FID) radiation of many transitions in molecule and heterodyne source has in time-domain the same information as usual frequency spectra. Observing of FID signals of different duration produced by various gas medium gives, according Fourier-transformation, different spectral resolution [1,3-8]. Continuous train of NovoFEL pulses with period 177 ns can be used for recording of fast spectral "cinema" with resolution up to 10^{-6} [4]. We studied dynamics of bearing and decay of shot-living OH-radical which is important product of many chemical reactions of burning and atmosphere processes [9]. Non-Faraday rotation of polarization in magnetic field was used for increasing sensitivity by separation of powerful excited NovoFEL pulse from weak useful FID radiation [6,7].

III. SUPER-HIGH-RESOLUTION SPECTROSCOPY

Hyper-fine comb-structure of NovoFEL radiation consist of narrow lines of relative width of $2\cdot10^{-8}$[10,11]. We can use the structure both for creation of powerful ultra-monochromatic tunable terahertz source [12] and specific comb-spectroscopy of ultra-high resolution [13].

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