High-order harmonic generation by relativistic plasma singularities

A. S. Pirozhkov[1], T. Zh. Esirkepov[1], T. A. Pikuz[2], A. Ya. Faenov[3], K. Ogura[1], Y. Hayashi[1], H. Kotaki[1], E. N. Ragozin[4], D. Neely[5], H. Kiriyama[1], J. K. Koga[1], Y. Fukuda[1], A. Sagisaka[1], M. Nishikino[1], T. Imazono[1], N. Hasegawa[1], T. Kawachi[1], H. Daido[6], Y. Kato[7], S. V. Bulanov[1], K. Kondo[1], and M. Kando[1]

[1] *Kansai Photon Science Institute, National Institutes for Quantum and Radiological Science and Technology (QST), Kizugawa, Kyoto, Japan*
[2] *Photon Pioneers Center in Osaka University, Suita, Osaka, Japan*
[3] *Institute for Academic Initiatives, Osaka University, Suita, Osaka, Japan*
[4] *P. N. Lebedev Physical Institute of the Russian Academy of Sciences, Moscow, Russia*
[5] *Central Laser Facility, Rutherford Appleton Laboratory, STFC, Chilton, Didcot, UK*
[6] *Naraha Remote Technology Development Center, Naraha, Fukushima, Japan*
[7] *The Graduate School for the Creation of New Photonics Industries, Hamamatsu, Shizuoka, Japan*
**E-mail: pirozhkov.alexander@ qst.go.jp*

Abstract: We discuss the new regime of high-order harmonic generation by relativistic-irradiance multi-terawatt femtosecond lasers focused onto gas jet targets [*PRL* **108**, 135004 (2012); *NJP* **16**, 093003 (2014)]. The laser induces multi-stream relativistic plasma flow resulting in the formation of density singularities: structurally stable, oscillating electron spikes coherently emitting high-frequency radiation. In this presentation we analyze the dependence of the harmonic yield on the laser power and focal spot quality, and derive the required laser parameters for efficient harmonics generation. We show the status of the J-KAREN-P laser and report on the progress towards satisfying these requirements.

In the new regime of high-order harmonic generation, intense ($>10^{18}$ W/cm^2) high-power (multi-TW) femtosecond (30-50 fs) laser pulses focused onto gas targets induce multi-stream relativistic flows in underdense plasma ($n_e \sim 10^{19}$ cm^{-3}). This results in the formation of density singularities, which are structurally stable, oscillating electron spikes coherently emitting high-frequency radiation with spectra comprising high-order harmonics [1, 2]. The experiments with the J-KAREN laser [3] demonstrated strong dependence of the harmonics yield on the laser pulse energy and focal spot quality.

In this presentation we analyze the obtained dependences and derive laser parameters required for efficient harmonics generation. Apart from higher power, it turns out that the focal spot quality should approach the diffraction limit, i.e. the Strehl ratio should exceed 0.5. The focal spots of high-power lasers typically suffer from wavefront distortions and angular dispersion. For noise-like wavefront distortions, the above stated requirement corresponds to an rms wavefront error <100 nm. The angular dispersion should be kept smaller than a fraction of the diffraction divergence, i.e. μrad level for 100 to 300 mm beam diameters. The corresponding angular chirp should be $<10^{-2}$ μrad/nm for 50 nm bandwidth. We show the status of the J-KAREN-P laser and report on the progress towards satisfying these requirements.

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2. A. S. Pirozhkov, et al., "High order harmonics from relativistic electron spikes," *New J. Phys.* **16**, 093003-30 (2014).
3. H. Kiriyama, et al., "High-Contrast, High-Intensity Petawatt-Class Laser and Applications," *IEEE J. Sel. Topics Quantum Electron.* **21**, 1601118-18 (2015).