High Harmonics from Solids - a Coherent Source of keV Radiation

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While the 21st century has been spontaneously nominated to the century of photon there is still open what photons from the broad available spectrum will dominate in the development. The latter depends strongly on the interest in the potential applications. The most fascinating fields revealed thanks to novel radiation sources are femto- and attosciences as well as the new possibilities in exploring the nano-world. On the other side of the scale the ultra-intense laser pulses produce new states of matter and extend the capabilities of existing scientific techniques and enabling the development of new ones.

On the basis of the brief history of the development in the field of X-ray lasers, high harmonics from gases and the incoherent short-wavelength sources the constraints on the existing and applied in practice sources will be discussed.. The grazing incidence pumping (GRIP) geometry of X-ray lasers reduced dramatically the necessary pump laser energy down to ~1 J (see Fig.1a). However, the conversion efficiency has been unchanged and the output of XRLs has also been reduced. The total efficiency of the X-ray laser remains at 10^{-6}. The high harmonics from gases deliver the

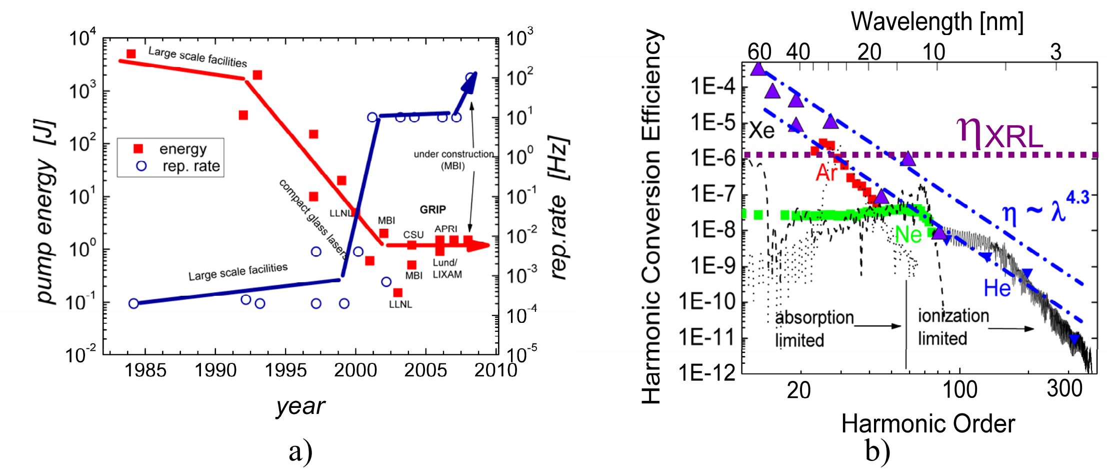

Fig.1 The history of the necessary pump energy (red) and the available repetition rate (blue) of the X-ray lasers a) and the conversion efficiency of the high harmonics from gases..

shortest available pulses but the conversion efficiency scales unfavourably towards the shorter wavelengths. It scales as $\eta \sim \lambda^{4-5}$ where λ is the wavelength of the radiation to be generated. (Fig.1b). The incoherent sources can deliver beams of radiation with a wavelength as short as 0.06 nm (20 keV) with a relatively high repetition rate but also these sources have limited conversion efficiency and moreover, they are difficult to beaming. The latter is crucial for application in practice. For this reason most of them work in the spectral range well below 10 keV and try to compensate efficiency deficit by high repetition rate (higher than 1 kilohertz).

Recently, a very attractive method of generation of keV radiation was vigorously pursued in its theoretical aspects but very scarce experimental data is available [1-4]. It concerns the relativistic harmonics from solids targets. The idea was generated 25 years ago and was based on the experimental observations during the inertial confinement (ICF) program [5]. As the laser technology could not deliver the laser driver of necessary characteristics the topic revived during the last few years when 100 TW lasers are easily available on the market.

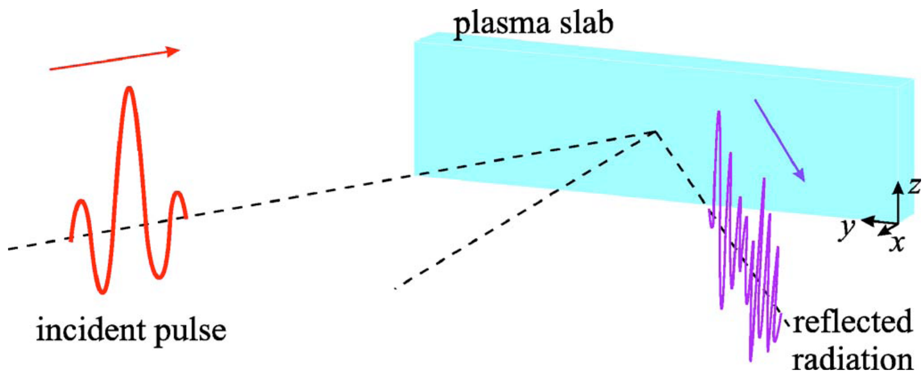

Fig.2 Principle of high harmonics generation from solids [3]

The technique requires relativistic intensities (about 10^{20} W/cm^2) and very short and clean pulses with a contrast C$\geq 10^{10}$. These are extremely challenging requirements but the big (PW-class) laser system being now built at APRI is perfect to explore this field. The generated short-wavelength radiation is the transformed primary radiation and the theoretical estimates promise unprecedented efficiency level depending on the emitted wavelength. For the spectral range of 20-70 eV the efficiency expected is equal to ~10^{-2}, for 70 -200 eV ~10^{-3} and up to 1 keV ~10^{-5} [2]. These values are 3 to 6 orders of magnitude higher than the conversion rates of other commonly applied sources. Moreover, the absolute values of the output energies are comparable or in lower energetic range even exceed those of the accelerator based X-ray free electron lasers.

Now it is the time come to confirm experimentally these high expectations. Advanced Photonics Research Institute (APRI) is preparing related experiment at its 100 TW facility. First step relies on preparation of a plasma mirror system improving contrast above 10^{10}. The plasma mirror system is being under construction as well as the diagnostic system. The experiment should be conducted in the beginning of the next year.

To summarize, the development of short wavelength technology at APRI starting with the successful experiments on generation and application of XUV radiation from X-ray laser is going to be continued in the direction of keV radiation and the high harmonics from surface of solids are a very attractive candidate to achieve a new source of exceptional features.

1. M. Zepf *et al., Phys. Rev. E*, 58, R5253 (1998)
2. G. Tsakiris et al.,, *New J. Phys*, **8**, 19 (2006)
3. T. Baeva, , S. Gordienko, A. Pukhov, *Phys. Rev. E.*, **74**, 046404 (2006)
4. B. Dromey *et al., Nature. Phys.,* **2**, 456 (2006)
5. R. L. Carman, D.W. Forslund, J.M. Kindel, *Phys. Rev. Lett.*, **46**, 29 (1981)