Collective nonlinear interactions in x-ray into ultraviolet parametric down-conversion

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Parametric down conversion (PDC) of x-rays into ultraviolet (UV) is a second order nonlinear process in which an x-ray photon (pump) interacts with the vacuum field via nonlinear media to generate an x-ray photon (signal) and a UV photon (idler). The method provides information about valence electron structure of the material via the interaction with the UV photons and the high spatial resolution is provided by the x-rays [1,2]. Nonlinear spectroscopy techniques based on this effect have already shown potential to be a powerful tool in solid-state physics [2]. However, the authors of all previous publications have considered only local atomic responses. Here we extend the study on nonlinear x-ray optics to include the effect of plasma oscillations. We explore the effect in a diamond crystal in the range of 25 eV - 54 eV where our model predicts resonances in that can be associated with the bulk plasmons shifted by different band transitions in the crystal.

Fig. 1 shows the measured dependencies on the idler photon energy of (a) the efficiency of the PDC and (b) the peak position of the signal beam. In (a) the arrows point at the photon energies at which the theory that includes the interaction with plasmons predicts peaks. The inset presents the simulation of the PDC process and the arrows point at energies that correspond to the position of the measured spectral peaks. In (b) the inset shows the rocking curves of the PDC at the photon energies near the sharp change in the peak position as a function of the idler photon energy.

Our results indicate on an unexplored field of nonlinear interactions between x-rays and plasmons and open the possibility for the development of a novel technique that will be used as a probe with atomic-scale resolution for collective excitations in crystals [3].

References