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TEMPERATURE DEPENDENCE OF LASER INDUCED HOT LUMINESCENCE OF SELF-TRAPPED EXCITONS IN SOLID XENON

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Self-trapped excitons (STE) in rare gas crystals (RGC) represent excimer-like (R_2^*) vibrational excitations, whose lower level spacings considerably exceed the highest phonon energies. Vibrational relaxation of such STE can be adequately described in terms of the recent nonperturbative quantum theory of multiphonon anharmonic decay of strong local modes [1].

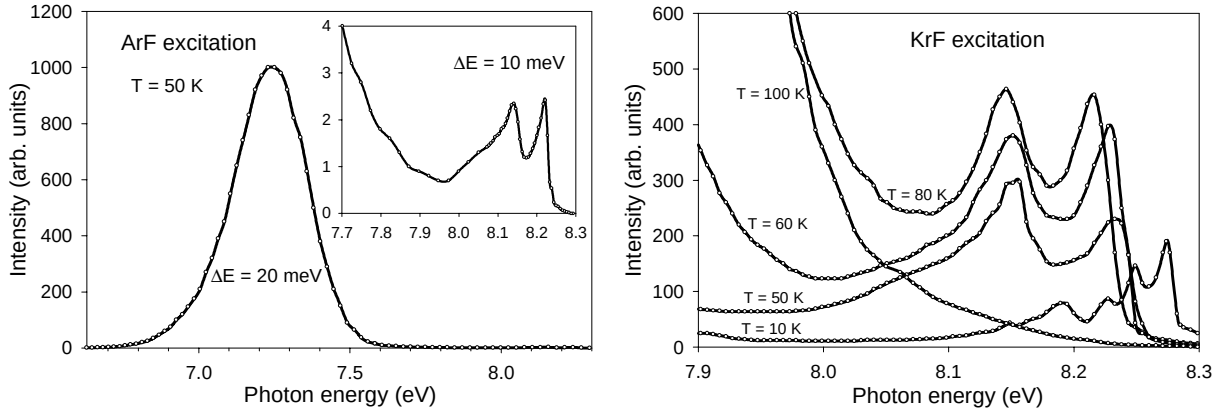

Figure 1: Hot luminescence spectra of solid Xe under different two-photon excimer laser excitation at various temperatures. The overall luminescence spectrum is shown in the major part of the left-side graph.

Useful information on the specific features of vibrational relaxation of STE in RGC can be inferred from their hot luminescence (HL) spectra. We present detailed experimental data and relevant theoretical analysis of the HL in Xe crystal. HL appears to be very sensitive to the crystal's quality and temperature, as well as to the kind of excitation used (see Figure 1). Two-photon KrF excimer laser excitation (10.0 eV), especially at low temperatures, produces more structured HL spectra compared with those induced by ArF (12.4 eV) laser excitation. At higher temperatures (T ~ 100 K) HL gradually disappears independent of the method of excitation. Although different in position and width, HL spectra of solid Xe always show up a deep hollow near 8 eV, already reported earlier [2, 3]. According to the general theory [1], this minimum arises from the abruptly increased relaxation rate in the characteristic "critical" range of vibrational levels ($n_{cr} \approx 23$) of Xe_2^*.

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Vacuum Ultraviolet Spectroscopic System for Solid State Materials

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Vacuum ultraviolet (VUV) continua emitting from a laser-produced plasma have been utilized for the spectroscopy of a solid state laser material. An absorption spectrum of 0.1% Nd:LaF_3 has been measured by use of the continuum emission. The minimum absorption coefficient of 1.4 cm^{-1} was evaluated at 174 nm.

Our VUV spectroscopic system consists of three parts; a plasma-initiating laser, a rare gas chamber where a plasma is produced and a sample is installed, and a VUV detection system. A Q-switched Nd:YAG laser was focused inside a pressurized rare gas chamber to produce a plasma. Typical emission spectra of three rare gases (He, Ne, Ar) are shown in Figure 1. At a laser intensity of 10^{11} W/cm^2, continuum emission dominates over line emissions for heavy rare gases. The emission intensity also becomes larger for heavier rare gases. Although the higher intensity has been observed for Kr, Xe [1], the resonant absorption of relevant atoms limits the wavelength range in the VUV. Note that the short wavelength range is limited by the cutoff of a MgF_2 window, which is used to separate the pressurized chamber and a sample. The long wavelength limit reflects on the sensitivity of a micro-channel plate. The wavelength-integrated emission power of the Ar continuum was measured to be 8.4 kW, which was large enough to obtain absorption spectra of solid state materials.

Figure 2 shows the absorption spectrum of 0.1%Nd:LaF_3 crystal by use of the Ar emission. Nd:LaF_3 has been known as a possible new VUV laser crystal around 172 nm [2]. Two samples with different lengths (0.9 and 5 mm) produced the same results. Our absorption spectrum has been a revised result of rather old spectroscopic data [3]. This VUV spectroscopic system is applicable to the evaluation of defects and a lifetime of VUV CaF_2 optics produced for F_2 laser optical lithography, with a help of FT-IR spectrograph.

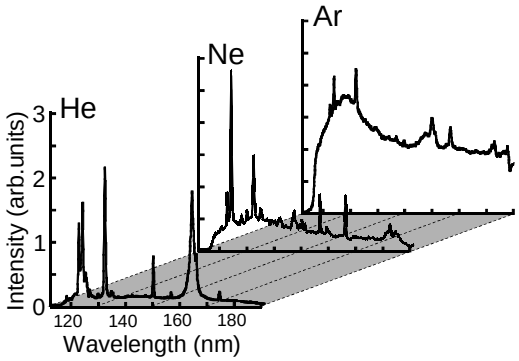

Fig. 1 Emission spectra of three rare gases.

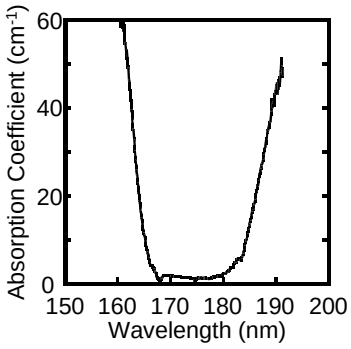

Fig. 2 Measured absorption spectrum of a 0.1% Nd:LaF_3 crystal.

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VUV SPECTROSCOPY OF CRYSTALLINE EMITTERS BASED ON 5d – 4f TRANSITIONS IN RARE EARTH IONS

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The interconfiguration 5d – 4f transitions in rare earth (RE) ions (Nd^{3+}, Er^{3+}, Tm^{3+}) doped into wide band-gap crystals can make possible laser action in the VUV [1]. However, up to date, the VUV laser emission from 5d – 4f transitions (172 nm) has been obtained only in Nd^{3+}-doped LaF_3 [2]. Neither different crystal hosts nor other RE ions have been tested for laser action in the VUV. On the other hand, complex fluorides provide a variety of crystal hosts with the desired symmetry and coordination number, as well with the different number of crystallographic sites for doping with RE ions. In the present paper the appropriate spectroscopic properties of several complex fluoride crystals (KYF_4, K_2YF_5, $KLiYF_5$, CsY_2F_7) doped with Pr^{3+}, Nd^{3+}, Er^{3+} or Tm^{3+} have been studied and analyzed from the viewpoint of their possible applications as active media for UV and VUV solid state lasers. The measurements of time-resolved excitation and VUV emission spectra as well as luminescence decay curves were performed under excitation by synchrotron radiation from the DORIS storage ring at the SUPERLUMI station of HASYLAB at DESY. The emission spectra were also studied under pulsed molecular F_2-laser excitation. The measurements of absorption spectra in the VUV were carried out with a deuterium lamp.

It has been found that in most of the crystals the intensity of the spin-allowed 5d – 4f luminescence of Er^{3+} or Tm^{3+} is extremely weak, i.e. in these crystals there exists very efficient nonradiative relaxation from higher lying 5d states to the lowest 5d level responsible for the spin-forbidden luminescence. In fact, the energy level diagram of 5d – 4f transitions for these two ions in some fluoride crystals represents a typical four-level laser scheme [3]. This peculiarity results in a larger Stokes shift of 5d – 4f luminescence from the edge of the strong spin-allowed 4f – 5d absorption for Er^{3+} and Tm^{3+} than for Nd^{3+}, which causes smaller re-absorption of emitted VUV radiation in the crystals doped with Er^{3+} or Tm^{3+}. Besides, relatively wide emission bands due to 5d – 4f transitions in these ions offer a possibility for tunable VUV laser design. One can expect that optical pumping, for example by the noble-gas discharge, in the wide spectral range of strong 4f – 5d absorption will be very efficient.

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A COMPARATIVE STUDY OF TEMPERATURE BROADENING FOR CROSSLUMINESCENCE AND SELF-TRAPPED EXCITON EMISSION

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The electronic structure and lattice geometry of emitting centers for different emission bands in the spectra of both kind intrinsic luminescence in ionic crystals, namely the self-trapped exciton (STE) luminescence and the crossluminescence (CL), are still under discussion. The studies of bandwidth as a function of temperature provide some indications on the nature of lattice relaxation around the emission center. The analysis of the temperature behavior of the bandwidths for both CL and STE emission spectra is based on the model of phonon broadening for the local optical center in the approximation of strong electron-lattice coupling: $W(T) = W(0)\times [\coth(\hbar\omega/2k_BT)]^{1/2}$, where W(T) and W(0) are the spectral widths of the emission band at temperatures T and T = 0, respectively, ω is phonon frequency, k_B is Boltzmann constant [1-3].

In the present work, the temperature dependencies of the bandwidths for STE emission spectra in several alkali halide crystals with high temperature of thermal quenching for STE emission (NaBr, KI, RbI, CsI) were studied and compared with a typical temperature behavior of CL spectra. The measurements were carried out at the SUPERLUMI station of HASYLAB under the excitation by VUV synchrotron radiation from the DORIS storage ring at DESY (Hamburg). The technique of time-resolved spectroscopy was used for the selection of fast (CR, singlet STE) and slow (triplet STE) components of luminescence.

The obtained results demonstrate that for the type II STE (weak off-center configuration) the coupling with "soft" phonon modes, corresponding most probably to the translation motion of X_2^- molecular ion (X is a halogen atom), is responsible for the thermal broadening of the emission band. For the STE type I (on-center configuration) and for the CL bands which show comparatively strong thermal broadening, the temperature dependence of the bandwidth is well described by coupling with phonons, the frequencies of which are close to characteristic frequencies of the host lattice vibrations. This feature indicates that the lattice structure of the emitting state for CL has the on-center character. However, for the CL bands with weak thermal broadening the model of the local optical center is not providing a reasonable explanation of the observed temperature behavior of the bandwidths.

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AN INTENSE XUV SOURCE AT A WAVELENGTH OF 13.5 NM FROM AN ABLATIVE CAPILLARY DISCHARGE

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Strong emissions of an XUV source at a wavelength of 13.5 nm are presented in this study. In particular this wavelength has attracted the attention of many scientists working in the field by being a good candidate for the development of EUV lithography. One of the main reasons for this interest is due to the speedy development of multilayer mirrors such as the Mo/Si which has a reflectivity of 69.5 % at a wavelength of 13.5 nm [1]. This source was generated by using an ablative capillary discharge where the capillary was made of PVC (polyvinyl chloride). A remarkable burst of radiation at the above mentioned wavelength was recorded. Figure 1 shows time resolved spectra of a capillary made of POM (polyacetal) in comparison to the one made of PVC. This figure shows clearly that the intensity of the radiation is higher by a factor of 10, in the spectral region of interest, when the capillary is made of PVC in comparison to that of POM. These spectra were recorded using a flat field spectrograph (grating 1200 line/mm) combined with a MCP whose phosphorous was imaged onto a CCD camera.

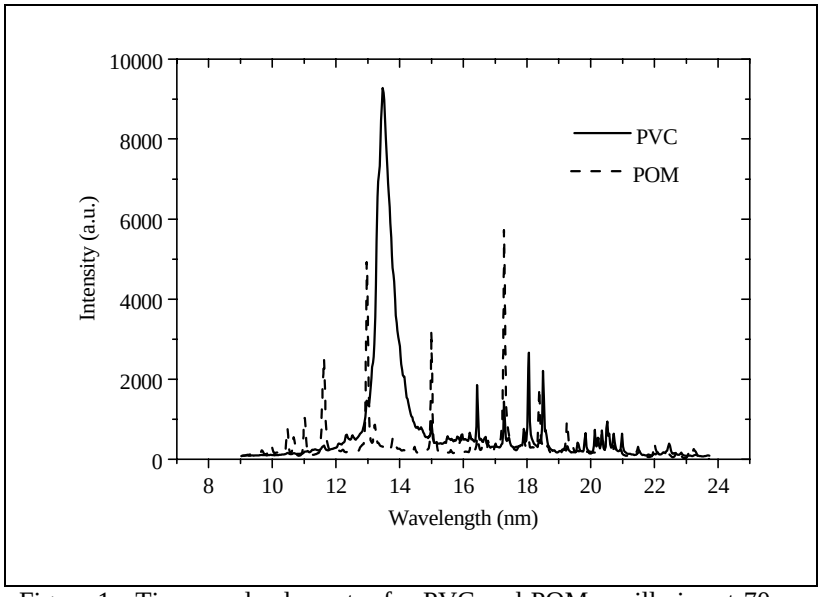

Figure 1: Time resolved spectra for PVC and POM capillaries at 70 ns from the beginning of the discharge.

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Study of the cathode sheath of high pressure discharge for XeCl excimer lasers

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abstract

The purpose of this work is to study the evolution of the cathode sheath of high pressure discharge for excimer lasers. In this region of discharge which is a transient between the plasma and the cathode, the electron field can reach high values until 10^6 v/cm. These elevated values are largely responsible of the development of the instabilities in plasma. We study also other phenomenons which have an influence on the stability of plasma; the secondary emission coefficient, the photoemission current at the cathode, the nonuniformity of the preionisation density and the transition avalanche-streamer.

We present here a simplified analytical description of the cathode sheath formation. A one-dimensional longitudinal model for the study of the cathode sheath has been developed. This model is based on continuity and momentum-transfer equation for electron and ions coupled with Poisson's equation. We use the numerical model MUSCL (monotone Upstream-Centred Schemes For Conservation Laws).

Keys: cathode sheath, instabilities in plasma, excimer lasers, numerical modelling.

PICOSECOND TIME-RESOLVED SPECTROSCOPY OF SOLIDS WITH VUV HIGH ORDER HARMONICS SOURCE

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A High Order Harmonics VUV laser source and its applications in investigation of electronic relaxation in solids are discussed. Femtosecond duration and high intensity Ti-sapphire laser pulses lead to direct generation in a gas of high order harmonics with a spectrum extended up to VUV-X region. The duration of the harmonic pulse is the same (or shorter) as that of the primary laser pulse. The main advantages for spectroscopic study with high order harmonics radiation are: quasi continuous spectrum in the VUV region (up to 500 eV), ultra-short pulse duration (20 fs – 1 ps), high pulse intensity (up to 10^{10} photons/pulse/harmonic), relatively high frequency of pulses (1 kHz) and table-top size. These properties offer new possibilities compared to the synchrotron radiation sources and pulsed X-ray tubes for the study of dynamics of the excited region created by VUV-X photon in solids. Spectroscopy with High Order Harmonics VUV source requires development of temporary non-perturbed beam-line optics and ultrafast detectors.

We describe the design of the VUV beam line composed of the high order harmonics generation chamber, VUV monochromator and experimental chamber. A 800 nm light beam from a 20 fs and 20 mJ laser chain operating at a repetition rate of 1 kHz [1] is used for harmonics generation in an hollow-core fiber containing a rare gas. The beam line was developed to study the high order harmonics properties and to perform time-resolved experiments in the picosecond range. We present the results on HH spectra studies and the results of the first time-resolved measurements of solid state fluorescence in the picosecond range.

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Measurement of the second order coherence of synchrotron radiation in VUV region

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The statistical nature of light is closely related to the mechanism by witch light is generated. We can estimate the statistical nature of light by measuring the second order coherence. This experimental method is useful for the diagnosis of present synchrotron radiation sources and Free-Electron Lasers. It also provides a technique for measuring the instantaneous elecron-beam emittance, while the averaged emittance was obtained by measuring the first order coherence.

In this study, we measured the second order coherence of synchrotron radiation (undulator radiation) in VUV region. The experiment was performed at the beamline BL-16B of the Photon Factory, KEK. Figure 1 shows the second order coherence (arbitrary units) as a function of the width of the fraunhofer slit. The second order coherence tends to increase with decreasing slit width. This result indicates the synchrotron radiation has a chaotic nature. We also estimated the electron-beam emittance by measuring the second order coherence and the beam size independently. The estimated emittance is lower than the designed value, which implies that the instantaneous emittance is actually smaller than the averaged one.

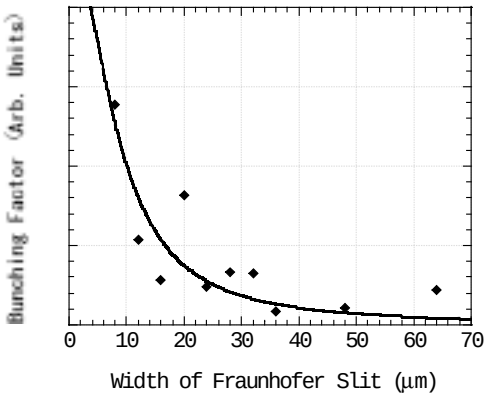

Figure 1: Bunching effect of the second order coherence of synchrontron radiation.

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STUDY OF COMPACT X-RAY LASER PUMPED BY PULSE-TRAIN LASER

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Tabletop x-ray lasers that are operated at shorter wavelengths less than 20 nm, are promising tools for many noble applications such as x-ray photoelectron spectroscopy, x-ray microscopy, x-ray holography and so on. Introducing a resonant cavity for the x-ray laser could improve the effective gain-length product of the system, which would contribute to reduce the required pumping energy, and could produce highly coherent x-rays.

We observed the amplification of Li-like Al soft x-ray transitions in recombining Al plasmas produced by a pulse-train YAG laser with an input energy of only 1.5-2 J/cm [1]. Furthermore we performed cavity experiments using multilayer mirrors for the Al XI 3d-4f transition line (15.47 nm). A clear enhancement of the lasing x-ray from the x-ray laser cavity was confirmed for the first time [2]. The cavity output has been characterized to have a beam divergence of about 3 mrad with an absolute intensity of approximately 10^8 photons/shot.

Recently we have performed an advanced experiment with the double-target configuration to improve x-ray laser output substantially. X-ray intensity of the 15.47 nm transition line has been enhanced. Half-cavity experiments in the double-target configuration were also performed, the enhancement of x-ray was also observed. The results in the half-cavity experiment were consistent with a simple estimation, where the two plasmas having positive gain-length products contribute to amplify x-rays passing through each plasma.

To measure the spatial coherence of our x-ray laser, an arrangement for dispersing coherent diagnostic has been constructed. It is consisted of several Young's double-slits, a transmission grating and an x-ray CCD camera. Preliminary results will be presented.

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Near field imaging of transient collisional excitation x-ray laser

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Since the first demonstration of x-ray lasers has been done, compact and applicable x-ray laser systems were intensively studied. Saturated amplification of x-ray laser with low pumping energy have been achieved by transient collisional excitation technique in Ne- and Ni-like series. X-ray laser with wavelength around 13nm is very useful for laser processing, since it is suitable for multilayer optics. In order to use x-ray lasers for various applications, it is indispensable to characterize the x-ray lasers in terms of the spatial gain profile, output energy, and the far field pattern.

We have been successful to generate x-ray lasers such as the Ne-like Ti (λ=32.6nm), Ni-like Ag (λ=13.9nm) [1], and Ni-like Sn (λ= 11.9nm) in transient collisional excitation scheme which is generated by use of a picosecond CPA hybrid laser system with pre-pulse technique. Measuring the spatial gain profile of the x-ray laser, a near field imaging system with magnification 10 was used. The near field imaging system was constructed with a concave mirror, two turning mirrors, and a soft x-ray CCD camera. The mirrors were coated with molybdenum/silicon multilayers for 13.9nm x-ray by NTT Advanced Technology.

The gain region was crescent shape and the size was 50μm. Inside the gain region localization of high gain area was also observed. We will report the near field imaging of the Ni-like Ag laser with several pumping pulse variations.

Reference

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THE BRIGHT SIDE OF THE FEL AT DESY: PHOTON BEAM CHARACTERIZATION OF THE ULTRA-INTENSE VUV RADIATION

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A single-pass free electron laser (FEL) based on the principle of self-amplified spontaneous emission (SASE) is currently under test at the TESLA Test Facility (TTF) at DESY [1-3]. In a second step, after completion of the test experiments in the VUV, the accelerator energy will be increased to 1 GeV to produce uniquely intense and extremly short-pulse radiation tunable down to 6 nm wavelength.

Up to now lasing has been achieved for wavelengths between 80 nm and 180 nm, while the highest SASE gain was observed about 100 nm. In comparison to spontaneous undulator radiation the photon density on axis has been increased by a factor of ≈ 200, and the angular distribution has been narrowed by more than a factor of three. Figure 1 shows a footprint of the FEL beam at 102 nm on a Ce:Yag crystal.

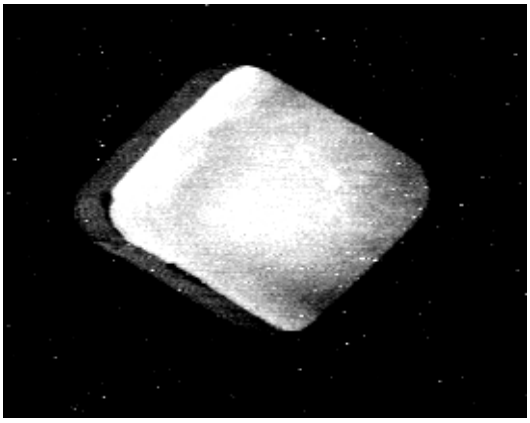

Figure 1: Footprint of the FEL beam at 102 nm on a Ce:Yag crystal.

This paper presents recent results and summarizes the techniques used for the determination of the photon beam intensity, its angular and spectral distribution, and its statistical properties [4].

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Single and two photon one electron removal Fermi edge spectra measured by a 150 fs coherent pulses on the Ag (110)

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The dynamical aspects of electron-phonon interaction play a crucial role in many properties of metals and has been studied both by indirect methods, like transient reflection techniques (Ref.1), and direct methods, i.e. pump and probe photoemission (Ref.2). In this work the single and two photon Fermi edge photoemission spectra of the Ag (110) surface are presented and discussed. Thanks to the very low noise (less than 10^{-2} electrons/s) of the time of flight spectrometer used to measure the photoelectron kinetic energy, we are able to observe in great details the non-equilibrium effects induced by a second order (two photons) photoemission process with respect to the direct photoemission obtained by a 6.28 eV-150 fs laser pulse. Particular emphasis is given to the non equilibrium heating of the electron gas and the consequent Fermi edge smearing effect.

In addition, the experimental set to produce the third (264nm-4.69 eV) and fourth (198nm-6.28eV) harmonics of an amplified Ti:Sapphire coherent source and the electron time of flight spectrometer is presented (Fig. 1).

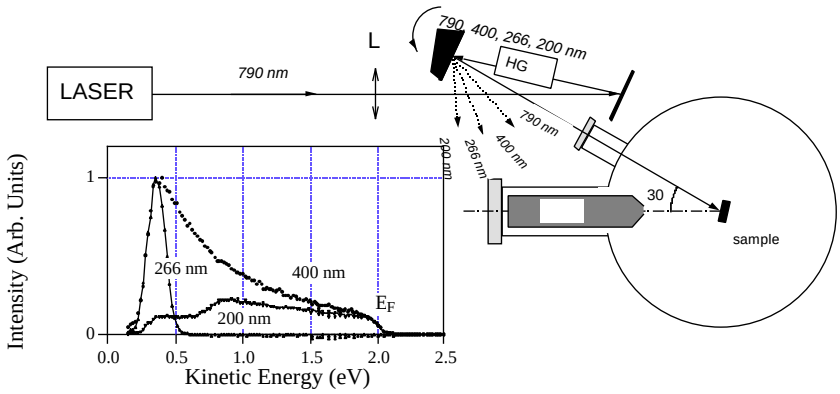

Fig. 1 - Experimental set up: harmonic generation and time of flight apparatus. In the graph some typical spectra taken with different harmonics of the laser pulses.

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Generation of short laser pulses at 130 nm-9.4 eV

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A new scheme for the generation of ultrashort pulses at a photon energy of 9.4 eV is discussed. We propose a simple arrangement, shown in Fig. 1. It is based on the third harmonic generation in a MgF_2 crystal induced by the second harmonic of the fundamental pulses from an amplified Ti:Sapphire laser system. Even with a pump energy of few tens of μJ, the number of VUV photons (Fig. 2) is suitable to use the device in spectroscopic time resolved studies. We also present a possible experimental arrangement for pump and probe angle resolved photoemission spectroscopy.

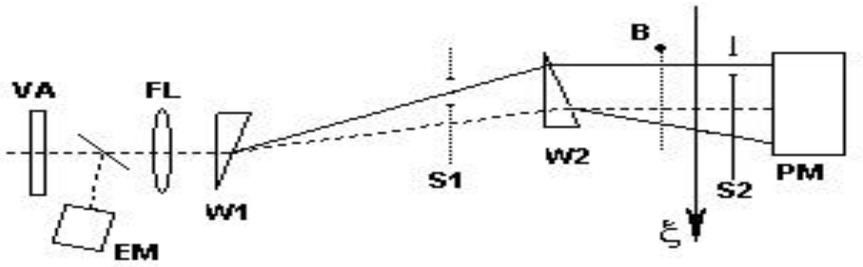

Fig. 1 - Layout (schematic) of the experimental set-up: VA variable attenuator; EM energy monitor; FL focusing lens; S1 and S2 apertures; W1 Magnesium fluoride crystal wedge where harmonics are generated; W2 dispersing magnesium fluoride wedge; PM solar blind photomultiplier; B glass plate, ξ is the polarization axis. Typical pump pulse parameters: time width: 150 fs, energy: 20 μJ, wavelength: 400 nm.

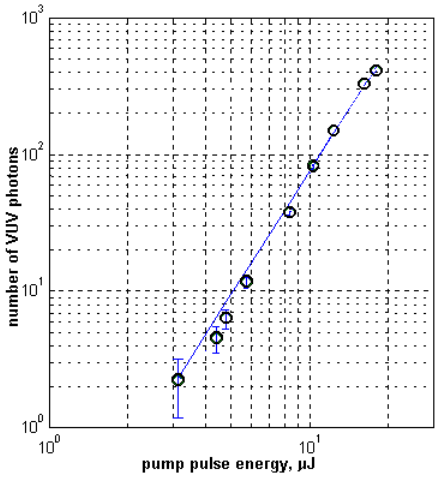

Fig 2 - Number of VUV photon generated per pulse versus the energy of the pump pulse.

Time-resolved x-ray absorption of laser-excited materials

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Laser sources currently produce ultrashort pulses at infrared, visible, and ultraviolet wavelengths, which can be used to study the dynamics of valence electrons in atoms, molecules, and solids. Alternatively, to probe structural and electronic properties, near-edge and extended x-ray absoption (XANES and XAFS) are powerful techniques. A femtosecond laser induces a phase transition or chemical reaction in a material. Time-resolved detectors and a fs x-ray source are used to obtain the x-ray absorption spectrum.

A fs x-ray pulse can be generated through the interaction of a fs laser pulse co-propagating with an electron bunch in a wiggler [1]. The fs laser pulse produces an energy modulation in the electrons. The accelerated electrons are then spatially separated from the rest of the electron bunch in a dispersive section (bend magnet). Finally, by imaging the radiation from the displaced electrons, it is possible to separate out the fs x-ray pulse. Pulses of synchrotron radiation with 300 fs duration have been measured.

Time-resolved x-ray absorption enables one to probe the electronic structure of materials at high temperature and near-solid densities. X-rays from the Advanced Light Source synchrotron are focused onto a thin foil sample, dispersed by a flat-field spectrometer and detected by a streak camera. The sample is heated at constant density by a fs laser pulse. X-ray absorption spectra of high temperature silicon at the L edge have been obtained with 8 x-ray pulses.

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Investigation of gas- jet debris-free laser plasma source of soft X-ray radiation in 11-14nm spectral interval.

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One of the key problems of the soft X-ray nanolithography is a development of debris-free laser plasma source. Debris generated by condensed matter targets cause unacceptable damage of the optic system. Development of the laser plasma source with a cluster gas jet exploited as a target can provide a solution of this problem [1,2]. Therefore, investigation of gas jet expanding into low pressure chamber is an important part of the gas jet target development.

Gas jet parameters, which determine intensity of cluster formation, are studied both by experimental and numerical methods.

A new experimental setup was built in order to carry out series of experiments that could provide necessary data concerning intricate structure of the cluster gas jets.

Numerical simulation was also performed to estimate parameters of jet and to analyze effects of nozzle shape, pressure ratio and gas characteristics. Effects of nucleation and the micro-droplet formation in the expending supersonic gas jet were also taken into an account. At the first stage of the investigations, the trial computations for confirmation of the simulating nozzle flow algorithm were accomplished under the various conditions [3] The developed approach has demonstrated good efficiency, flexibility and accuracy. It enables us to consider shocked flows which are characterized by the complex structure and interphase transfer processes. The jet structure and parameters (density, velocity and temperature fields) were determined as well as a fraction of the condensed matter and micro-droplet parameters. Experimental investigation of the soft X-ray radiation from the laser plasma source based on the supersonic gas jet target using absolutely calibrated detector is planning to be carried out.

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Radiance of Laboratory Plasma Source for Extreme Ultraviolet Lithography.

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One of the fast developing area of intensive impulse plasma sources application is the industrial approach to nanolithography using radiation in the wavelength range around 13 nm (photon energy~100 eV), i.e. so-called Extreme Ultraviolet Lithography (EUVL). The sources applicable for nanolithography have to meet many stringent requirements, but one its characteristic of great importance is absolute radiance (photons/sr..s.nm.cm^2). The procedure of absolute radiance calculation has been analyzed and standard approach [1] for estimation of emission characteristic for different kind of impulse plasma sources in spectral interval of interest is proposed. Contrastive studies and calculations of absolute radiance of source designs used and proposed for EUVL technique are presented and compared with synchrotron radiation and high harmonic generation facilities.

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A table-top soft X-ray source based on 5-10 MeV LINACs

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Relativistic electrons emit Cherenkov radiation when they are sent through a foil. This effect is well known in the visible wavelength region, but it can also be put to use in the VUV and soft X-ray region to generate narrow-band radiation [1]. Generally, in those wavelength regions the refractive index is smaller than unity, but shows resonant behavior around inner-shell absorption edges. Due to this effect the refractive index of some materials exceeds unity in narrow wavelength regions and may fulfill the Cherenkov condition (e.g. Al, Si, C, Ti, V). Radiation is then emitted in a narrow wavelength band and with a high directionality (Cherenkov cone). Moreover, moderate electron energies, i.e. 10 MeV up to 25 MeV, which can be obtained from table-top accelerators, are sufficient to produce the maximum output power from a single foil. The combination of such small accelerators and the Cherenkov radiation characteristics enable a high brightness, laboratory sized source in the VUV and soft X-ray region. Applications can be found in a variety of fields, such as X-ray microscopy, X-ray fluorescence analysis of low Z element contamination and EUV lithography.

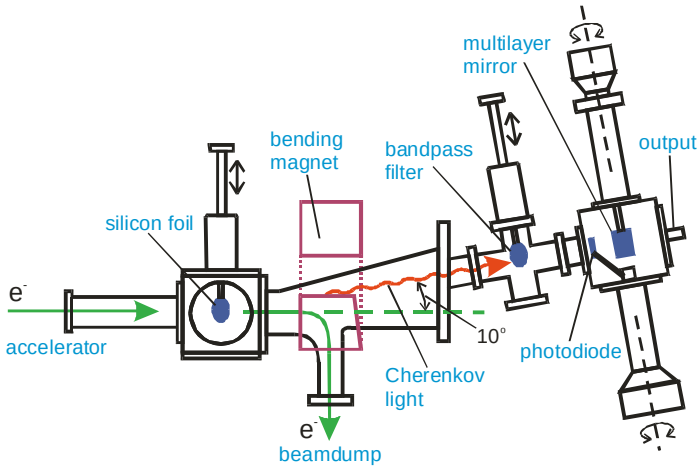

Figure 1: Experimental setup of silicon L-edge (100 eV) Cherenkov radiation measurement.

Just recently we established the generation of silicon L-edge Cherenkov radiation by 5 MeV electrons [2]. In the detector set-up we used a Si/Mo multilayer mirror as wavelength dispersive element. By changing the angle of incidence we could perform a small wavelength scan through the Cherenkov 'line'. The radiation from the multilayer mirror was projected on a photodiode specially prepared for 100 eV by a zirconium bandpass filter.

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VUV spectroscopy of new fluoride system NaF-(R,Y)F_3

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Lasers operating in the vacuum ultraviolet (VUV) spectral region are of great importance for different applications such as selective photochemistry, biology, isotope separation, laser induced thermonuclear fusion, photolithography, etc. The interconfiguration 5d – 4f transitions in rare earth (TR^{3+}) ions (Nd^{3+}, Er^{3+}, Tm^{3+}) doped into wide band-gap crystals provide possibilities for laser action in the VUV [1,2].

The transparency of matrix crystals $Na_{0.4}R_{0.6}F_{2.2}$ based on R= Y, Lu in VUV has been measured. Limits of transmittance were located at 127,2 and 132,5 nm, respectively. Such a remarkable property as dopeability by all triply ionized rare earth ions in a wide range of concentrations makes these matrixes extremely promising for the creation of new emitting media for VUV region.

Emission, absorption and excitation spectra of new complex fluoride system $Na_{0.4}(Y_{1-x}R_x)_{0.6}F_{2.2}$ (x = 0.05 – 1) have been studied in the VUV spectral range. It has been shown that these crystals have intense VUV luminescence due to the interconfiguration 5d – 4f transitions beginning from 165 nm.

This makes the studied new fluoride system a promising active media for the production of VUV solid state laser with optical pumping. Due to rather large bandwidth of TR^{3+} 5d – 4f luminescence in this system there is a possibility for the construction of tunable VUV laser [3].

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POWERFUL SOURCE OF BROADBAND VUV-RADIATION BASED ON MULTI-CHANNEL SLIDING DISCHARGE

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The development of powerful sources of broadband UV-VUV radiation is important for various scientific and industrial applications, such as laser optical pumping, ionization of gases, treatment, disinfection and decontamination of various objects, and others. From this view point, optical sources based on a multi-channel sliding discharge exhibit many perspective features. Being compared with diffuse sliding discharge ("plasma-sheet"), which possesses a large radiating area and a low electrical circuit inductance, the initiation in parallel of multiple narrow plasma channels allows obtaining enhanced VUV-radiation characteristics.

To obtain high values of electric power deposition into the discharge plasma, we designed a fast electrical circuit which did not incorporate any separate high-voltage switching device [1]. The discharge gap breakdown was initiated by conductive plasma channel of barrier discharge, which was formed by short high-voltage pulse applied to the trigger electrode. On this basis a large-area optical source was designed, which consisted of 47 parallel discharge channels of 20 cm long positioned 1.2 cm apart. Electrical circuit of the source realizes remarkably fast power deposition into the discharge plasma: up to 4 kJ during 1.5 μs. The discharges were initiated in the Ar/N_2 mixture under pressure of 1 bar. Total photon flux produced by the source within the 120-200 nm spectral range reaches the value of 10^{26} photons/s.

The latter value is estimated on the basis of absolute measurements of VUV radiation from single-channel discharge, which were carried out by method of spectrally-selective dynamic actinometry [2]. Absolute values were deduced from the analysis of the photodissociation dynamics of a small amount ($<10^{17}$ cm^{-3}) of XeF_2 molecules added to the gas mixture, as well as the registered evolutions of plasma boundary radius and VUV radiation power and spectrum. The dynamics of XeF_2 dissociation wave produced under discharge VUV radiation was monitored by blue-green fluorescence of excited XeF(C) molecules formed in the wave front. We examined the VUV-radiation from 20-cm-long single-channel discharge along Teflon substrate. The discharge of a storage capacitor of 0.22 μF charged up to 40 kV produced electric current pulse of 14 kA in maximum and FWHM of 0.9 μs, which exhibited a good impedance matching with the load. The photon flux intensity emitted by plasma surface within the 120-200 nm spectral range reached the value of $(6.2\pm1.0)\times10^{23}$ photons/cm^2s (corresponds to the equivalent black-body temperature of 25±1 kK).

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SPECIFIC FEATURES OF SOFT X-RAY BREMSSTRAHLUNG ON SCATTERING OF INTERMEDIATE ENERGY ELECTRONS BY ARGON ATOMS

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It is accepted that the bremsstrahlung (BS) cross-section at the atom scattering of a nonrelativistic electron decreases with increasing energy of the electron [1]. But when recording the differential spectra of BS in the ultra-soft X-ray region (USX) on scattering of intermediate energy electrons by Ar atoms, an increase in the BS intensity with rising the electron energy has been observed. This fact has given impetus to a thorough investigations of intensity (I) of the BS differential spectrum in the USX region versus energy of electrons (E) scattered by Ar atoms. It is the results of the investigations that are the objective of the report.

The experiments were carried out at single collisions on a setup consisting of an X-ray tube with an argon supersonic jet (used as an anticathode) and an X-ray spectrometer RSM-500 [2]. The dependences I(E) were measured at wavelengths of 6.5 to 10 nm (where the polarization BS contribution is insignificant) with an electron energy varying from 0.3 to 2 keV. The electron beam current was 10 mA for all electron energies. The Ar atom concentration was 2.3×10^{16} cm^{-3} at the electron-jet intersection. The angle between the directions of motion of the incident electrons and the photons analyzed was 97^0. The solid angle of BS sampling was 1.7×10^{-3} steradian.

For each of the wavelengths studied it is found that the BS intensity increases as $I(E) \sim E^{1/2}$ with increasing the electron energy from 0.3 to 0.7 keV and then it decreases as $I(E) \sim 1/E^{1/2}$ with rising the electron energy from 0.8 to 2 keV. Note that the decrease in the intensity, $I(E) \sim 1/E^{1/2}$, does not agree with that calculated in the Born approximation [1]. Based on the analysis of the experimental data in terms of the Jouch-Rorlich low-energy theorem [1, 3], we believe that the increase in the BS intensity with the electron energy is responsible for by the increase of the opened channels of atom excitation and ionization that accompany the braking effect, i.e. by the contributions of inelastic BS processes. The decrease in the BS intensity with increasing energy from 0.8 to 2 keV is due to the decrease in the contributions of the “inelastic” BS.

Thus, the USX bremsstrahlung in the region with intermediate energy electrons scattered by Ar atoms cannot be described in the Born approximation. In parallel with the elastic BS processes, the contributions of the inelastic BS processes should be taken into account.

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Atomic ionization experiments in absolute terms

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Synchrotron radiation was used as a basic element for the development of a method and an apparatus that provides the accurate measurement of ratios of absolute total cross sections for photoionization and electron-impact ionization in rare gas atoms. The method is based on the comparison of ion yields resulting from ionization of rare gases by electrons and photons. The ratios of total cross-sections for electron-impact ionization and photoionization in Ne, Ar, Kr, and Xe were measured with relative uncertainties as low as 1 to 2 % in the energy range from 140 eV to 4000 eV for electrons and from 16 eV to 1500 eV for photons. It enabled us to deduce total electron-impact ionization and photoionization cross sections of rare gases with relative uncertainties below 3 % [1,2]. An upgraded version of the experiment is scheduled for absolute flux monitoring on the VUV-FEL at DESY.

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A Fourth Generation Light Source Facility for the UK

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Free electron lasers are the latest generation of accelerator-based advanced light source, providing a unique combination of tuneability, coherence, polarisation, time-structured pulses and high laser power. The proposed facility, 4GLS, will consist of a low energy storage ring with insertion devices and a cavity-based VUV-FEL, together with a stand alone linac-based infrared free electron laser (IR-FEL). These sources range from the far infrared to the extreme ultraviolet and they offer ultra-high intensity within a facility layout which will encourage flexible and innovative use.

This work will describe the facility currently proposed and will discuss the predicted performance and opportunities for exploitation.