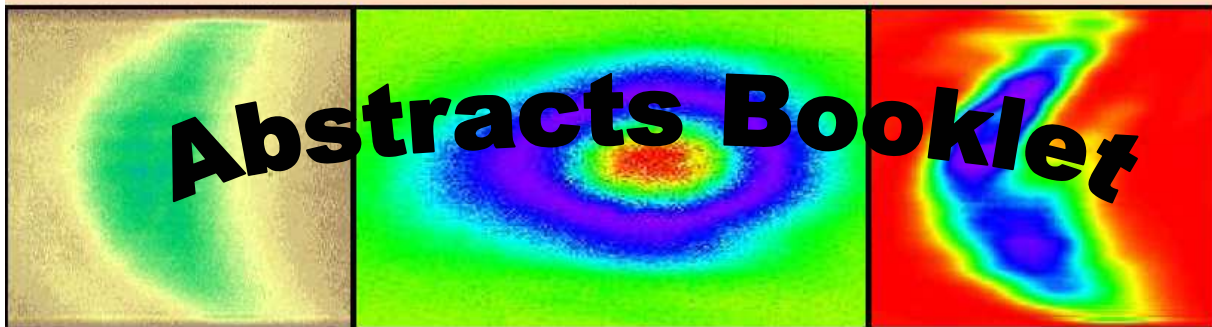




Workshop sur les  
**Opportunités Scientifiques en  
France d'une source de 4<sup>ème</sup>  
génération d'énergie  
intermédiaire**

Institut Henri Poincaré 11 rue Pierre et Marie Curie - 75005 Paris

**23 & 24 octobre 2008**



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With the advent of the first x-ray lasers world-wide, this workshop aims at bringing together scientists from all disciplines interested in exploring the revolutionary capabilities of these new sources, which will provide fully coherent, femtosecond short x-ray pulses of exceptional brightness. For instance, with accelerator-based free electron lasers (FEL) about ten orders of magnitude will be gained on peak brightness with respect to today's synchrotron radiation storage rings. Therefore, one may expect a spectacular development of the entire field of x-ray science, comparable to the revolution of optical science due to the advent of femtosecond lasers. The future x-ray lasers will thus bridge a gap by extending the performance of optical lasers to the x-ray photon energies and the workshop aims at bringing together these two communities.

Linear accelerator-based SASE and seeded FEL sources are today the most mature instruments for achieving the above ultimate performance. A suite of next generation x-ray sources has been proposed by the ARC-EN-CIEL project, which predicted performance can be taken as a benchmark for a future x-ray source. Besides, laser-plasma based electron accelerators become possible today and will offer alternative schemes. All these sources will have their own characteristic strength and be most suitable for one particular photon energy range or a specific type of application. The interested users are therefore invited to express their scientific visions and needs. Together we aim at identifying key experiments that will redefine the technical requirements and thus determine priorities for the performances of a future x-ray light source in France.

All participants are encouraged to contribute to the workshop program. Overviews about experiments already performed at or planned for existing or future x-ray lasers will be given by invited speakers. These presentations will introduce specific scientific fields or experimental techniques and will be followed by contributed talks chosen from the submitted abstracts. One session will be dedicated to parallel working groups, which aim at the formation of teams with a common experimental interest. This process is also envisioned to stimulate new experiments at existing or currently developed x-ray laser sources.

The workshop has been generously supported by:



# ORAL CONTRIBUTIONS

## MULTIPLE IONIZATION/EXCITATION OF ATOMS AND IONS IN XUV SHORT FIELDS

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With the advent of x-ray laser sources like free electron lasers (FEL), it is now possible to provide fully coherent short wavelength sources that feature femtosecond pulses reaching intensities larger than  $10^{14}$  W/cm<sup>2</sup>. Such laser fields may induce non-linear processes in atoms and ions. A recent example of application is the observation of two-photon double ionization of helium using the FEL FLASH source [1], similar experiment have been realized using soft-x ray produced by high order generation [2].

Strong field multiple ionization/excitation with several active electrons is a fundamental problem in atomic physics and a challenge for both experiment and theory. Because of the canonical importance of multiphoton processes in helium, a large number of theoretical works have focused on two-photon excitation of autoionizing states (AIS) and two-photon double ionization (TPDI) in helium. Concerning autoionizing states, the lower 1Se and 1De AIS series of He are excited from fundamental state through two-photon absorption with  $\hbar\omega \cong 30$  eV [3,4]. TPDI channel opens for photon energies larger than 40 eV, a considerable amount of works have focused on this problem these last years. The difficulty of this problem is that the highly nonlinear field interaction is entangled with the few-body correlated dynamics. For photon energies ranging from 40 eV to 54.4 eV the two-photon double ionization process is direct, in this range there exists two clusters of calculated cross-sections, separated by more than one order of magnitude (see [5], other references therein). One reason for such a difference might be the different treatment of electron interaction in the final double continuum state. However, this clustering of theoretical data cannot be explained by categorizing them with respect to account or neglect the electron interaction in final state. Besides TPDI cross-sections, calculations of electron energy distributions also show discrepancies [5]. With photon energies larger than 54.4 eV and fs pulses, He TPDI is a two step process; one-photon ionization of He (step 1) followed by one-photon ionization of He<sup>+</sup> (step 2). The resulting electron spectrum shows two peaks associated to steps 1 and 2, respectively. For ultra short pulses (sub-fs), the electron spectrum deviates from the spectrum obtained with fs pulses and the concept of direct or sequential ionization loses its pertinence. Thus TPDI electron spectrum reveals electron dynamics at the attosecond scale [6,7].

Future sources, delivering ultra short x-ray pulses, will lead to a new research area in non-linear optics as well as correlated quantum dynamics.

### References:

- [1] A.A. Sorokin, M. Wellhöfer, S.V. Bobashev, K. Tiedtke and M. Richter, Phys. Rev. A 75 (2007) 051402(R)
- [2] H. Hasegawa, E.J. Takahashi, Y. Nabekawa, K.L. Ishikawa and K. Midorikawa, Phys. Rev. A 71 (2005) 023407
- [3] I. Sánchez, H. Bachau and E. Cormier, J. Phys. B 28 (1995) 2367
- [4] R. Hasbani, E. Cormier and H. Bachau, J. Phys. B 33 (2000) 2101
- [5] E. Fomouo et al, J. Phys. B 41 (2008) 051001
- [6] S. Laulan, Thèse de Doctorat, "Etude des atomes d'hélium et de béryllium en champ laser intense et bref", Université Bordeaux 1 (2004), S. Laulan and H. Bachau, Phys. Rev. A 68 (2003) 013409, same authors, Phys. Rev. A 69 (2004) 033408
- [7] E. Fomouo, Ph. Antoine, H. Bachau and B. Piraux, New J. Phys., 10 (2008) 025017

## Ultrafast magnetization dynamics and electronic structures of Co clusters, films and alloys

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The magnetization dynamics of nanometric ferro or superparamagnetic 3d films and particles can be studied using core level spectroscopy and time resolved X-ray magnetic circular dichroism (XMCD) under femtosecond laser excitation.

Time resolved XMCD experiments performed at the 3d transition metal core edges bring insight into the dynamics of the relevant microscopic parameters. XMCD is the unique opportunity to obtain the spin and orbital contributions to the magnetic moments of 3d transition metal atoms with picosecond or femtosecond time resolution. Moreover the chemical selectivity of the core level spectroscopy offers the possibility to select individual component of complex systems. The long delay ( $t > 100$  ps) re-magnetization associated to the thermal diffusion, the fs-slicing magnetization dynamics ( $t < 500$  fs) and the precession of the spins have recently been explored as a function of magnetic field and temperature. The work was performed for Co films and clusters using the f-slicing experiment at the BESSY synchrotron storage ring.

## Ultrafast structural dynamics in proteins

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Proteins are able to accomplish their biochemical function thanks to their very specific structure, but the knowledge of the static structure of these molecules does not fully reveal how they work. Their functioning relies on their capacity to efficiently adopt distinct configurations. This is why determining intermediate 3D structures of proteins during biological processes is essential.

X-ray diffraction with a synchrotron source was recently used to make a movie of a heme protein reaction with a 150ps-temporal resolution [1]. However, the very first events take place on the time scale of internal protein vibration [2]. Therefore, we need techniques for visualizing internal movements with atomic resolution, and with a temporal resolution down to 100fs. We have developed an amplified femtosecond source (12mJ, 150fs, 1kHz) and a vacuum chamber which allows us to obtain 300fs duration, 1.5 Å wavelength X-ray pulses with a photon flux of  $5 \times 10^9$  photons/s/sr. We performed an x-ray diffraction experiment on a lysozyme crystal [1], an enzyme widely found in animals and plants. The crystal of protein is placed outside the vacuum chamber but as close as possible to the divergent source.

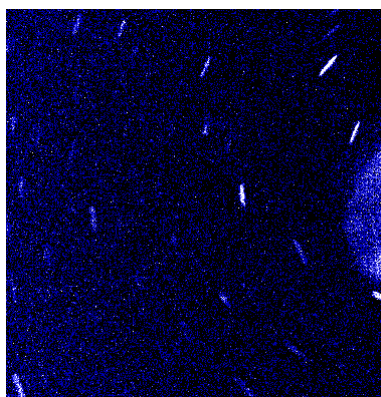


Figure 1: Diffraction pattern from a lysozyme crystal obtained with a laser-plasma source

We will present preliminary results on x-ray diffraction from proteins using a laser plasma source, and different methods of excitation, electronic or vibrational[4], that could bring the protein into a transition state.

[1] F. Schotte, M. Lim, T.A. Jackson, A.V. Smirnov, J. Soman, J.S. Olson, G.N. Jr Phillips, M. Wulff, P.A. Anfinrud, *Watching a protein as it functions with 150-ps Time-Resolved X-ray crystallography*, *Science* **300**, 1944 (2003)

[2] M.H. Vos, F. Rappaport, J.C. Lambry, J. Breton, J.L. Martin, *Visualization of coherent nuclear motion in a membrane protein by femtosecond spectroscopy*, *Nature* **363**, 320 (1993)

[3] A. Bonvalet, A. Darmon, J.-C. Lambry, P. Audebert et J.-L. Martin, *1-kHz table-top ultrashort hard x-ray source for time-resolved x-ray protein crystallography*, *Opt. Lett.* **18** **31** (2006)

[4] C. Ventalon, J.M. Fraser, M.H. Vos, A. Alexandrou, J.-L. Martin, M. Joffre, *Coherent vibrational climbing in carbonmonoxyhemoglobin*, *Proc. Natl. Acad. Sc. (USA)* **101**, 13216 (2004)

## ARC-EN-CIEL – An intermediate energy of 4th generation X-ray source project

M. E. Couprie, A. Loulergue, C. Benabderrhamane, O. Chubar, J. C. Denard, P. Dumas, J. M. Filhol, M. Idir, M. Labat, P. Lebasque, A. Lestrade, M. Louvet, P. Marchand, O. Marcouillé, P. Mercère, L. Nadolski, L. Nahon, P. Morin, *Synchrotron SOLEIL, Saint-Aubin, France*; C. Bruni, *Laboratoire de l'Accélérateur Linéaire*; D. Garzella, *CEA/DSM/IRAMIS/SPAM*; G. Lambert, P. Zeitoun, *Laboratoire d'Optique Appliquée, Palaiseau, France*; L. Giannessi *ENEA, Frascati, Italy*

The ARC-EN-CIEL (Accelerator-Radiation for Enhanced Coherent Intense Extended Light) project is aiming at offering a suite of novel photon sources for serving a diverse scientific community. This project optimised at intermediate energy originates from the various demands expressed by several user communities since 2004. Because of the required 1-10 kHz repetition rate, the choice for a superconducting linear accelerator was adopted. It will deliver a 1 GeV electron beam with a charge of 1 nC and electron bunches length of 200 fs RMS, that will feed seeded Free Electron Laser sources for providing radiation down to 1 keV with adjustable polarisation. Energy recovery and reacceleration loops could be added in a second step, providing additional sources at a MHz repetition rate: sub-picosecond synchrotron radiation to 20 keV from insertion devices implemented on the loops, a FEL oscillator at short wavelength and a seeded FEL radiating at shorter wavelength thanks to the energy enhancement up to 3 GeV in the loops.

Several FELs (named LEL1, LEL2, LEL4) would provide an extensive energy range of pulsed, high power radiation flux. They rely upon High Gain Harmonic Generation (HG) radiation and their Non Linear Harmonics seeded with the High Order Harmonics generated in Gas (HHG).

LEL1 will cover the 200-1.5 nm spectral range with adjustable polarisations and with 100-30 fs FWHM pulses at a few kHz.

LEL2 will provide 10-0.6 nm radiation with planar polarisation, in 100-30 fs pulses at a few kHz repetition rate.

LEL4 will cover the 2-0.2 nm range, with 50-30 fs pulses at 1 kHz.

These FEL sources will reach MW to GW of peak power. Meanwhile the innovative concept of HHG seeding was proposed on ARC-EN-CIEL, collaborations on SCSS Test Accelerator in Japan and SPARC in Italy were set up for its experimental demonstration. Seeding at 160 nm from HHG was achieved on the SCSS Test Accelerator<sup>1</sup>, showing a significant spectral narrowing as compared to Self Amplified Spontaneous Emission leading to an enhancement of the temporal coherence and a shortening of the saturation length. Radiation on the FEL harmonics is also easily achieved.

LEL3, a FEL oscillator in the 40-8 nm range with a repetition rate of 4.5 MHz, could provide a source complementary to the seeded FEL because of its high average power.

In addition, short period in vacuum undulators located on the recirculation loop could offer 300 fs pulses radiation with energies above 20 keV, whilst soft-X rays could be obtained from variable polarisation undulators.

Because of the very short electron bunches, THz will be naturally produced and available for user applications.

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<sup>1</sup> *Injection of harmonics generated in gas in a Free Electron Laser providing intense and coherent extreme-UV light* G. Lambert, T. Hara, D. Garzella, T. Tanigawa, M. Labat, B. Carré, H. Kitamura, T. Shintake, M. Bougeard, S. Inoue, Y. Tanaka, P. Salières, H. Merdji, O. Chubar, O. Gobert, K. Tahara, M. E. Couprie, *Nature Physics* 4, 296-300 (2008).

The ARC-EN-CIEL project was initially phased according to the required electron beam energy for construction and budget constrains (phase 1 @ 220 MeV (resp. phase 2 @ 1 GeV) providing radiation down to 30 nm (resp. 1 nm) and phase 3 with 1 and 2 GeV loops).

The ARC-EN-CIEL Conceptual Design Report has been recently completed<sup>2</sup>. Integrating innovative and original concepts, ARC-EN-CIEL aims at developing the synergy with radiation sources based on conventional lasers and optics/beamlines developments, such as the example of HHG seeding or taking advantage on the knowhow on multilayer optics in the soft X ray range for the FEL oscillator at short wavelength. Combination of lasers and FEL sources is largely envisioned for pump-probe experiments.

Next development and studies intend to assess the choice of accelerator type with respect to the requested repetition rate, to further analyse seeding issues and ultimately to investigate the integration of plasma acceleration. Different ways of producing ultra-short pulses will also be considered. Whilst the 10 fs range seems achievable providing a proper synchronisation between the accelerator equipment and the laser systems is implemented, schemes for reaching attosecond pulses could also be considered, even though not yet demonstrated experimentally so far.

This project is presented as an example to show the possibilities that a fourth generation light source could offer for novel scientific applications. The various optimisations, the maturity of the modelisation tools, and the experience acquired in seeding<sup>3</sup> is making this project still flexible for modifications to fulfil at best the new scientific requests, as expected to be expressed during this workshop. In particular, the relevance of the defined FEL and spontaneous emission beamlines (number, spectral range, properties, repetition rate) is open for discussion.

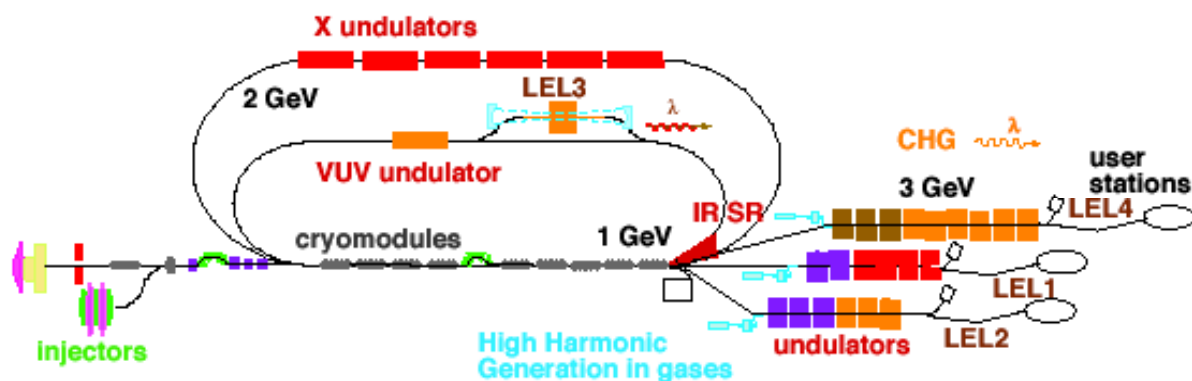


Fig. General scheme of ARC-EN-CIEL proposal

<sup>2</sup> <http://www.synchrotron-soleil.fr/ArcEnCiel>

<sup>3</sup> *Optimization of a seeded Free-Electron Laser with helical undulators*, M. Labat, M. Hosaka, M. Shimada, M. Katoh, M.E. Couprie, accepted in Phys. Rev. Lett.

## Ultrafast Photoswitching studied by Time-resolved RX and Optical Techniques.

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Controlling with an ultrashort laser pulse molecular states in a solid material represents a next step in ultrafast science, ensuing the now established field of femtochemistry. Molecular materials offer the possibility to be directed between different macroscopic states by using appropriate electronic excitations as, contrary to dilute solutions, all the constituent molecules in solids can be photoactive. This opens new avenues for light-control of various photoswitchable functions (magnetic, optical, conduction...), with some direct consequences for future developments of information technologies. Development of both time-resolved RX and optical techniques is essential for a good understanding of the mechanisms at all different time scales.

The early stage of the photoinduced process is presently discussed in two limit cases: the first one corresponds to delocalised electronic excitations giving rise to collective atomic vibration and as such was investigated by ultra-fast x-ray Bragg diffraction [1]. The second case corresponds to localised molecular excitations as illustrated by the ultrafast photoinduced spin conversion in a new Fe(III) solid [2,3]. Different subsystems associated with degrees of freedom of different nature are involved and therefore the out-of-equilibrium dynamics span through several consecutive steps from sub-picosecond up to the microsecond.

More complex situations can be encountered in molecular charge-transfer systems where the early delocalized electronic excitation can be trapped by lattice relaxation, giving rise to the generation of precursor short-range ordered clusters. Such situation was recently investigated in the case of the photoinduced neutral-to-ionic transformation in the molecular charge-transfer compound TTF-CA. In this system, the direct evidence of an ultra-fast laser-induced ferroelectric order had been obtained by 100 ps X-ray diffraction experiments performed at the ESRF [2] and KEK, as well as the reverse photo-induced transition [3]. A photo-generation process involving the formation of one-dimensional nano-domains of lattice-relaxed charge-transfer excitations, as recently observed at thermal equilibrium [4], is the most probable scenario as shown by the first time-resolved diffuse scattering measurements.

- 1- SOKOLOWSKI-TINTEN K. *et al. Nature* **422**, 287-289 (2003).
- 2- COLLET E., BURON-LE COINTE M., LORENC M., CAILLEAU H., *Zeitschrift für Kristallographie* **223** 272-282 (2008).
- 3- LORENC M. *et al*, submitted
- 4- COLLET E., LEMÉE-CAILLEAU M.H, BURON-LE COINTE M., CAILLEAU H., WULFF M., LUTY T., KOSHIHARA S., MEYER M., TOUPET L., RABILLER P., TECHERT S., *Science* **300**, 612 (2003).
- 5- GUÉRIN L., COLLET E., LEMÉE-CAILLEAU M.H., BURON-LE COINTE M., CAILLEAU H., PLECH A., WULFF M., KOSHIHARA S., LUTY T., *Special issue of Chem. Phys.*, “Ultrafast Science with X-rays and Electrons”, **299/2-3** 163-170 (2004).
- 6- BURON-LE COINTE M., LEMÉE-CAILLEAU M.H., CAILLEAU H., RAVY S., BÉRAR J.F., ROUZIERE S., ELKAÏM E., COLLET E., *Physical Review Lett.* **96** 205503 (2006).

## Momentum imaging experiments on photo double ionization of atoms by XUV laser sources

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Numerous theoretical studies have been recently devoted to the photo double ionisation (PDI) of helium by two XUV photons. Surprisingly they give contradictory predictions, not only for the absolute integral cross sections, but also for the energy distribution over the two electrons, which is found to be either maximum or minimum at equal sharing [1].

The physical interest of such energy distribution will be briefly discussed, on the basis of Wannier theory. Although some information is carried by the recoil ion, the detection of electrons is required for unambiguous determination of the energy distribution and angular correlations.

Recent PDI experiments of such type, using momentum imaging, have been performed on xenon by using harmonic generation in the XUV range, combined with infrared radiation [2]. The main issues of such multiphoton experiments will be discussed, in the perspective of the 4th generation XUV sources.

### REFERENCES:

[1] E. Fomouo, Ph. Antoine, B. Piraux, L. Malegat, H. Bachau and R. Shakeshaft  
J. Phys. B: At., Mol. Opt. Phys., 41, 2008, 051001

[2] O. Guyétand, M. Gisselbrecht, A. Huetz, P. Agostini P., B. Carré, P. Breger, O. Gobert, D. Garzella, J.-F.Hergott, O.Tcherbakoff, H. Merdji, M. Bougeard, H. Rottke, M. Bottcher, Z. Anzari, P. Antoine and L. Di Mauro.  
J. Phys. B : At. Mol. Opt. Phys., 41, 2008, 065601

## **Temporal characterization of femtosecond and attosecond XUV pulses**

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The temporal characterization of ultrashort laser pulses in the visible domain often relies on the use of nonlinear crystal. The direct transposition of these techniques into the XUV range is thus difficult. In the past few years a number of new measurements schemes have been proposed and implemented, achieving temporal characterization of XUV femtosecond and attosecond pulses produced by high order harmonic generation. I will review the different existing techniques and discuss their possible implementation on free electron lasers.

## **Ultrafast electron dynamics in strongly correlated materials**

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There are many experimental techniques employing X-ray radiation that are currently used to explore the electronic properties of strongly correlated materials. In particular, spectroscopies employing a photon-in photon out approach - like inelastic scattering - present particular advantages for these investigations.

The advent of fourth generation light sources offers the opportunity of extending these methods to the study of excited states of matter and dynamics of phase transitions, thus disclosing new possibilities to answer basic questions concerning the physics of these materials, and to show their potential for technology.

## Ultrafast X-ray coherent diffraction imaging

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Ultrafast coherent diffraction using soft and hard X-rays is actually revolutionizing imaging science thanks to new sources recently available. This powerful technique extends standard X-ray diffraction towards imaging of non-crystalline objects and leads actually to a strong impact in physics, chemistry and biology [Miao et al., Nature 1999]. New ultrashort pulses recently available make it possible to image individual nano-systems in space and time with unrivalled resolutions.

Imaging few nanometers to micron size individual objects, with a nanometer resolution in space and a femtosecond resolution in time, constitutes today a fascinating challenge essentially out of reach of established techniques. The new ultra-short and coherent x-ray sources – especially the Free Electron Laser (FEL) and the High laser Harmonics (HHG) – are the appropriate tools to bridge the gap. In 2006, the first single shot ultrafast coherent diffraction pattern was measured on isolated non-periodic nano-sample at the FLASH soft X-ray Free Electron Laser (Hamburg) [Chapman et al., Nature Physics 2006]. More recently the same team has achieved a time resolved experiment with 100nm, 10ps space and time resolutions [Barty et al., Nature Photonics 2008]. The recent availability of ultrashort coherent table-top soft X-ray pulses has opened up similar perspectives. A very high output (microjoule range), femtosecond coherent soft x-ray source from laser HHG in gases has been developed at CEA-Saclay. A first result in coherent imaging has been obtained very recently. Coherent diffraction patterns of isolated objects have been obtained on the HHG source in single shot. Using controlled sample, our current set-up allows reaching a resolution of 70 nm and potentially a time resolution of 20 femtosecond. This already validates the potential of our soft X-ray source to perform time resolved studies of ultrafast processes at a nanometer scale.

Preliminary Study on a Resonance-Fluorescence Experiment  
using the New Generation XUV Monochromatic Sources  
for Hot and Dense Plasma Spectroscopy

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The new generation XUV sources provide the possibility to give a better knowledge of dense plasma properties by allowing active spectroscopy experiments.

In this context, we present a schematic description of a resonance fluorescence experiment using monochromatic sources to observe radiative redistribution on multi-electrons ions.

The frequency redistribution in hot and dense plasmas has presented a high interest for a few years with the development of monochromatic and intense x-ray lasers with wavelengths appropriate for photopumping ground-state transitions of multi-electron ions. Since the X-ray lasers are not tunable, only ionic transitions that have a near resonance with specific laser wavelengths have been studied.

The next generation sources (tunable, narrow-band X-ray sources) should allow to pump individual transitions of a line profile emitted by a hot and dense plasma and then measure radiative redistribution.

The study of the redistribution of resonance radiation in hot and dense plasmas has important implications for the understanding of population kinetics, radiative transfer and fundamental processes of the plasma. We have developed a model for calculating the redistribution function in hot and dense plasmas for the study of a two-photon process, more precisely the scattering of resonance radiation.

## **Time resolved photoelectron spectroscopy of highly correlated materials**

Luca Perfetti

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Time resolved photoelectron spectroscopy exploits femtosecond laser sources to measure the electronic states in photoexcited samples. The dynamics of electronic spectra provide direct access to spectacular phenomena as coherent lattice motion, photoinduced phase transitions and hot phonons generation. We will discuss our recent results on Mott insulator, charge density wave materials and high temperature superconductors.

## **Time-Resolved dynamics of Molecular Systems**

Lionel Poisson

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The reaction dynamics of molecular systems has been investigated in several groups in France. We will present here the general concept of this kind of studies and present some results obtained recently that might be improved by the use of ARC-EN-CIEL. We will conclude by proposing the benchmarks needed for the use of the FEL by the groups of our field.

## **Converting laser light to x-rays using clusters**

Christophe Prigent, Emily Lamour, Jean – Pierre Rozet, Martino Trassinelli, Dominique Vernhet

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Large clusters, similarly to solids, couple very efficiently to intense subpicosecond laser pulses. In the case of IR photons, near 100 % of the laser radiation can be absorbed, leading to the observation of highly charged ions with energies reaching MeV and electrons with energies up to a few keV. A fascinating feature of this interaction is its efficiency for converting photons in the eV range to x-rays with keV energies. Whereas the spectroscopy of the emitted ions and electrons extracts information from the system a few microseconds after the femtosecond laser pulse and the cluster disintegration, x-ray spectroscopy allows performing measurements on a very short time scale. Even though only ions with inner-shell vacancies contribute to X-ray spectroscopy, their observation gives access to the dynamical evolution of the irradiated cluster on a time scale comparable to that of the laser pulse duration. Since the inner-shell vacancies are produced by electron-impact ionisation, KeV X-rays provide an in situ “thermometer” of the hot electrons in the cluster, acting as a probe of the energy distribution. The talk will present recent experimental results on large rare gas clusters and a comparison with a new theoretical development using microscopic calculations based on Monte Carlo simulations. An outlook will be given concerning the possibility to use the new 4th generation light sources.

## **Utilisation de la cohérence en diffraction**

Sylvain Ravy

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From X-ray diffraction experiments performed with synchrotron radiation, we will discuss some opportunities given by 4th generation sources

## **Laser-driven ultrafast X-ray sources**

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The recent development of ultra intense laser systems has permit the emergence of a large variety of x-ray sources covering broad spectral range from extreme ultraviolet to hard x-ray region. This presentation will summarize the actual status of the most powerful laser driven x-ray sources, coherent or incoherent. Moreover we will also discuss the possibility to combine different type of radiation and particle sources produced by laser for pump-probe experiments. Finally, the user access to these laser driven x-ray sources will be evoked.

## Angular and dynamical aspects after multiphotonic absorption in the gas phase probed by X-Ray emission

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The tender X-Ray region (2-12 keV) is particularly interesting because one can excite inner shell with very short lifetime ( $< 1$  femtosecond) and observe ultra fast processes. The brilliance of third synchrotron radiation facilities has recently allowed successful X-Ray emission measurements in the gas phase. [1-3]. We have performed an experiment/theory comparison of the linear dichroism observed on resonant Ka emission on HCl and CF<sub>3</sub>Cl molecules allowing a quantitative determination of the molecular field [4].

Our project is to probe multi photon absorption by X-Ray emission on molecules. If several photons are absorbed, one can probably excite a deep inner shell which de-excitation by X-Ray emission is of particular interest. Energetic and angular analysis of emitted photons will be performed by solid state detectors. We have chosen this kind of detectors because both of their large solid angle detection. In a second step, we will use an X-Ray spectrometer developed in our lab allowing high resolution and polarization dependence measurements. Our strong theoretical support from LCPMR will help us to understand the data. The experience of our international team on synchrotrons and on XFEL (LCLS) is a key of the success of this project.

Our plan is to use photons delivered by a fourth generation synchrotron facility in the energy range between 500 eV and 2 keV.

### References

- [1] J. Szlachetko et al., Phys. Rev. Lett. 97, 073001 (2006)
- [2] M. Simon et al., Phys. Rev. A 73, 020706 (2006)
- [3] M. Žitnik et al., Phys. Rev. A 76, 032506 (2007)
- [4] R. Guillemin et al., Phys Rev. Lett. accepted (2008)

## **Multiphoton and multicolor ionization using Free Electron and IR Lasers: Achievements & Perspectives**

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We present results from both experiment and theory on ionization of atomic helium and xenon by femtosecond extreme-ultraviolet (XUV) pulses from the Free Electron Laser at DESY. We discuss the conditions for observing both single-color multiphoton ionization or multicolor ionization when combining the XFEL with intense light pulses from a synchronized laser. These sets of experiments pave the way to multiphoton ionization/or excitation in the XUV regime. We will discuss some experiments that could be carried in and show the high intensity usefulness of Free Electron Laser sources.

P. Radcliffe et al, *Appl. Phys. Lett.* 90, 131108 (2007).

M. Meyer et al, *Phys. Rev. A.* 74, 011401(R) (2006).

V. Vénier et al., *Phys. Rev. Lett.* 74, 4161-4 (1995).

### **Overview of short-wavelength FEL facilities**

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Short-wavelength free-electron laser (FEL) radiation in the soft and hard x-ray domain is currently becoming available for user experiments. Since 2005 FLASH at DESY, Hamburg, is in operation as the first user facility for VUV to soft x-ray FEL radiation. Further facilities for the soft x-ray regime are under construction in Europe. In parallel, the construction of facilities for the hard x-ray domain has started. First hard x-ray FEL radiation is expected to be obtained in 2010 at the Linac Coherent Light Source at SLAC, Stanford and shortly after by the SPring-8 X-ray FEL project (Harima). By 2014 the European XFEL in Hamburg will provide hard x-ray regime. Further facilities for the hard x-ray regime are under preparation. In the talk an overview of the various facilities under construction and preparation and their specific designs and anticipated radiation properties will be given. An overview of outstanding scientific results obtained at FLASH and general aspects of the user access programs of operating and upcoming FEL facilities will be given allowing some insight on the scientific usage of these new facilities opening new avenues in addition to synchrotron radiation and optical laser facilities.

# POSTERS CONTRIBUTIONS

## Next Generation EUV Light Source For Metrology Applications

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Facing the challenging industrial requirements for EUV metrology and lithography applications, a new form of plasma radiation sources has been developed over the past decade by EPPRA, within a number of European and National research projects.\* Unlike all other plasma radiation sources, the new source possesses an in-built plasma collimating structure (PCS) which collects and projects the radiation forward in a preferred direction, similar to a lens. The new source is based on an ultra rapid electrical discharge within a very small volume, allowing very high energy density plasma to be created ( $>0.1\text{MJ/cc}$ ) with less than 1 J of energy input. The radiation is emitted in a time scale of several tens of nanoseconds. The PCS projects the radiation to a mm diameter spot at a distance of tens of cm away from the source. The collimating structure influences the radiation angle and produces a very small source etendue, below  $10^{-4}\text{ mm}^2\cdot\text{sr}$ . Using a pair of Mo/Si multilayer mirror as a band pass selector,  $> 1.4 \cdot 10^{11}$  photons around 91 eV (4% bandwidth) have been measured at a distance of 67 cm from the source in a single shot, over a spot of  $5\text{ mm}^2$ . The peak radiation power density recorded thus exceeds  $1.5\text{ kW/cm}^2$ . Operating at 2 kHz, an average irradiance of  $1.2 \cdot 10^{16}$  photons(91eV)/ $\text{cm}^2/\text{s}$  have been measured. This is comparable to that from a synchrotron beam line. Currently, the technology is being transferred to NANO-UV for commercial development.

Details characteristics of the radiation source and the measurements will be presented.

\* EU projects FACADIX, SOARING, More Moore; Eureka project T405

## Ultrafast X-Ray solution scattering reveals an unknown reaction intermediate in the photolysis of Ru<sub>3</sub>(CO)<sub>12</sub>

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The triangular metal carbonyl cluster Ru<sub>3</sub>(CO)<sub>12</sub> has served as the paradigm for the photochemistry of transition metal carbonyls. Previous studies using time-resolved infrared spectroscopy have identified two transient photochemical intermediates, Ru<sub>3</sub>(CO)<sub>11</sub>(μ-CO) for the metal-metal cleavage reaction channel and Ru<sub>3</sub>(CO)<sub>10</sub>(μ-CO) for the CO loss reaction channel. Here we report identification of a new intermediate as well as the two known intermediates by ultrafast X-ray scattering. Modeling of the time-dependent scattering curves on the basis of possible intermediates calculated by density functional theory and MD simulations clearly indicates that major and hitherto undetected intermediate is the Ru<sub>3</sub>(CO)<sub>10</sub> complex which has only terminal carbonyls and therefore has escaped from previous ultrafast infrared detection based on distinct infrared absorptions of bridging carbonyls. Our results illustrate that both time-resolved scattering and time-resolved spectroscopy are indispensable complements in revealing the detailed reaction dynamics.

Reference: Q. Y. Kong, J. H. Lee, A. Plech, M. Wulff, H. Ihee, M. H. J. Koch, *Angew. Chim. Int. Ed.* 2008, 47, 5550.

### New electron spectrometer for pulsed photon sources

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We report on the development of a novel instrument for electron spectroscopy dedicated for pulsed photon sources. The new spectrometer, the ARTOF 10k, is based on the time of flight principle but is combined with a lens system in order to increase the acceptance angle, and conserve the angular information of the photoemission in a full ±15° cone, allowing high precision ARPES and large solid angle transmission measurements. The ARTOF 10k is recently enhanced to allow for kinetic energies up to 1 kV as well as repetition rates beyond 1 MHz, that makes the spectrometer compatible with a wide range of photon sources such as lasers and synchrotrons. Development is also ongoing to customize the detector system for dedicated use at Free Electron Laser facilities.

## **Arc en Ciel an important tools for the study of excited electronic states of Biomolecular cations in the gas phase**

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Gas phase studies offer through mass selectivity and photoelectron time resolved studies, a sensitive tool to study and characterize the relaxation pathways after photo excitation of complex molecule like biomimetic species. We are currently studying the ultrafast decay of metalloporphyrins containing various transition metals with partially filled 3d and shells and zinc (3d filled). These experiments show different behaviours for zinc and transition metal porphyrins. The relaxation mechanism is well described by a simple model of porphyrin to metal charge. In the future, we would like to extend our studies to cationic species which are widespread in the living world. Arc en ciel with its tunability and its high photon flux would be an ideal tool for these studies. We propose to couple the Arc En Ciel light source with a velocity map imaging mass spectrometer. This set up will allow us to measure precisely the ionisation potential of metalloporphyrins and ligated metalloporphyrin which are unknown and the metal ligand bound strength, via the change in recoil of the ion fragments.

## **The Elettra storage-ring free-electron laser: a new seeded FEL facility for EUV-VUV ultra-short optical pulses.**

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We have implemented on the storage ring free electron laser beamline at Elettra an experimental setup for the generation of sub-picosecond coherent optical pulses in the VUV range. The setup is based on the (SINGLE-PASS) frequency up-conversion of a high-power external signal (provided by a Ti:Sapphire laser) and makes use of a relativistic electron bunch as resonating medium. The produced pulses have peak power in MW range, duration of about 100 fs, variable polarization, high shot to shot stability and control of the timing parameters at the ps level. We describe the experimental setup and present a characterization of the obtained radiation. Results show that the source we have implemented may be attractive for the investigation of dynamical phenomena, non-linear physics, magnetism and biology. Moreover, it is an ideal test facility for the development of the experimental techniques that will be applied on the future 4th generation light sources.

## X-ray laser takes the 100 Hz barrier

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Plasma based X-ray lasers (XRL) emitting coherent light pulses in the extreme ultraviolet range (EUV) have already taken the barrier the large scale facilities to table top laboratory devices. This development was accompanied by new pumping schemes and the availability of proper compact pumping lasers. The next step to be taken in the development of laboratory XRL's is the enhancement of the repetition rate. This would strongly broaden its application variety in material sciences, imaging, spectroscopy and laser plasma diagnostics, because a higher throughput e.g. in nanostructuring or a faster data acquisition e.g. in spectroscopy and imaging would benefit from a higher repetition rate.

During the last few years the optimization of XRL pumping schemes led to a dramatic reduction of the required pump energy for a saturated regime. With grazing incidence pumping (GRIP) scheme an energy level as low as 1 J was demonstrated for a saturated XRL operation. This pump energy could be provided in principle even by commercially available Ti:Sa laser systems. However, the repetition rate of these systems is limited to 10 Hz and the output stability of the XRL follows that of the pumping laser.

To overcome this situation a dedicated high repetition rate XRL pumping laser will be introduced here. This concept is based on a fully diode pumped solid state laser (DPSSL) using thin Yb:YAG disks as active material. Efficient pulsed diode stacks, tailor-made for this project allow repetition rates up to 100 Hz. The pump laser is designed as a chirped pulse amplification (CPA) system in order to warrant the required short pulse option.

In this talk we report about the first phase of the project aimed at a high average power 13.9 nm (Ag) XRL station in the GRIP scheme. According to this arrangement the CPA thin disk laser driver provides two different amplifier chains allowing to optimize both pulse duration and energy for the preheating (~ 200 ps pulse duration and up to 300 mJ energy) and the heating pulse (~ 5 ps up to 1 J).

The front end consisting of an Yb:KGW oscillator and regenerative amplifier is followed by a grating stretcher (for 3 ns pulses). All following amplifiers chains are based on modular multipass Yb:YAG thin disk laser technology. This allows a relatively easy up-scaling of the output energy by enlarging the disk diameter and the beam size. All amplifiers are fully pumped by the newly developed pulsed diode stacks which guarantee a repetition rate of up to 100 Hz limited only by the thermal load of the pump diodes. Before the last power amplifier the beam is split and then amplified in two parallel beams to the final energy in the short as well as long pulse. Both pulses pass independently through the same compressor.

For the following XRL operation a water cooled Ag or Mo- tape as target for 13.9 nm or 18.9 nm single line XRL emission was developed. The target speed can be adjusted to the high repetition rate of the driver laser.

In the first stage the output is expected to be limited to a few hundred nJ in < 10 ps pulses according to a photon flux of >  $10^{11}$  ph/s. This high averaged photon flux will be delivered within a beam of ~3 mrad divergence and a bandwidth of only  $\Delta\lambda/\lambda = 10^{-4}$  which is an outstanding parameter e.g. for experiments in imaging and spectroscopy. After the commissioning of the XRL station and first experiments demonstrating the high average power and stability an energy upgrade of the CPA thin disk pump laser is planned to increase the output energy of the envisioned 13.9 nm Ag-XRL to the  $\mu$ J range as well as to shorten the XRL output wavelength.

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### Short abstract about our field of interests

In our lab we are interesting in synthesizing blue  $Zn_{2-x}Co_xSiO_4$  pigments with low cobalt content. The powder obtained is characterized by several techniques: X-rays diffraction powder, IR and UV-Visible spectroscopy, LAB colour measurement, and Scanning Electron Microscopy. Comparative study was made between our synthesized pigments and the most used commercial pigments produced by different companies.

Our purpose is to experiment the synchrotron sources facilities to improve our investigation of the synthesised pigment. Indeed the increased brightness, tunability, low divergence and low emittance of X-ray beams available at new generation synchrotron X-ray sources facilitate a variety of powder-diffraction experiments not practical using conventional in-house sources. Furthermore, the increased availability of fast position-sensitive detectors, along with implementation of improved software, make possible new classes of experiments. These include time-resolved powder-diffraction of phase transitions, precipitation, recrystallization and ion-exchange reactions.

Recently we have used via telepresence the Synchrotron Radiation Source, at Daresbury (J. E. Warren et al), in experiments involving two research centres (UK and Morocco), both pursuing research interests in colouration chemistry (Bartalucci et al., 2007; Thalal et al., 2005). An additional fruit of the experiment is the chance to plan further experiments involving similarly weakly scattering crystals from our laboratories.

**Thalal, A.**, Ahamdane, H., El Idrissi Raghni, M. A. & Bensamka, F.(2005).  
Acta Cryst. A61, C390.

Bartalucci, G., Coppin, J., Fisher, S., Hall, G., Helliwell, J. R., Helliwell, M. & Liaaen-Jensen, S. (2007). Acta Cryst. B63, 328–337.

J. E. Warren, G. Diakun, G. Bushnell-Wye, S. Fisher, **A. Thalal**, M.  
Helliwell and J. R. Helliwell  
J. Synchrotron Rad. (2008). 15, 191–194

## On the spectra of the some fullerene ions

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In this paper we presented the results of our many-body calculations of the corresponding spectra of the some fullerene ions. In the paper is demonstrated the existence of the giant plasmon oscillations, their shape and the positions. The obtained results are of the interest from the theoretical and experimental point of view (for example, for the design of new materials in the nano domain, at the first).

## Study of the $L_{2,3}$ edges of 3d transition metals by x-ray absorption spectroscopy

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In the soft x-rays energy region, near edge x-ray absorption fine structure (NEXAFS) spectra are generally recorded by monitoring yield signals of secondary particles. These secondary particles, electrons or fluorescence photons, follow from the decay of the core hole excited in the primary absorption process. In general the yield signals are, to a good approximation, proportional to the absorption coefficient. However, in several applications it would be desirable to measure the absorption coefficient quantitatively. To derive the absorption coefficient quantitatively from a yield spectrum, one needs to know the escape depth of the emitted electrons ( $\lambda_e$ ) of the applied yield technique in the material of interest. Since this quantity is difficult to calculate, it is unknown for most materials. In this paper we present the first results of our systematic investigation of the total electron yield (TEY) escape depth of the 3d transition metals (Fe, Co and Cu). In addition our results gave important information on the variation of the TEY escape depth with the filling of the 3d band.

## **Diffusion Raman X exaltée par la diffraction de Bragg dans une structure multicouche périodique La/B<sub>4</sub>C**

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L'intensité du rayonnement x mou émis par une structure multicouche périodique La/B<sub>4</sub>C a été mesurée en mode non dispersé en fonction de l'énergie du rayonnement incident  $E_{inc}$  dans le domaine 125-200eV pour différents angles de diffusion. Ce domaine spectral recouvre le seuil 4d du lanthane. Nous avons observé un pic d'intensité diffusée pour des valeurs d'énergie  $E_{inc}$  qui décroissent quand l'angle de diffusion s'accroît. Ce phénomène qui n'avait jamais été rapporté par d'autres équipes, a été interprété comme étant dû à de la diffusion Raman par le niveau 5p du lanthane assistée par la diffraction de Bragg dans la structure périodique. Un modèle cinématique a été développé qui rend compte des observations. Néanmoins ce modèle fait plusieurs hypothèses qu'il serait souhaitable de vérifier expérimentalement. En particulier il faudrait analyser spectralement le rayonnement diffusé, c'est à dire effectuer des mesures de type RIXS sur ce système. Ce type de mesure nécessiterait une source de 4<sup>ème</sup> génération compte tenu de la faible intensité de l'émission. Ce phénomène de diffusion que nous avons appelé Bragg-Raman ouvre d'intéressantes perspectives dans le cadre de l'optique non linéaire dans le domaine du rayonnement X mou.

## **Studies of isolated nanoparticles with high intensity ultra short X-ray pulses of various energies.**

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We propose to use ultra short, highly brilliant X-ray pulses to study isolated nanoparticles (ie. nanoparticles in gas phase). Indeed, with the use of ultra-short pulses and pump-probe type of experiments it should be possible to study reactions on the surface of the nanoparticles (it is well known that a number of nanoparticles show a catalytic effect) with a time resolution not yet available at 3<sup>rd</sup> generation synchrotrons.

With a (hard) X-ray free electron laser radiation it would be possible to perform single shot diffraction or holography on isolated nanoparticles. In such experiments it would not only be possible to see the atomic structure of an individual nanoparticle, but also how molecules attach to the surface of nanoparticles.

In the proposed approach nanoparticles will be injected into UHV via an aerodynamic lens, see Ref. [1] and references therein, and several differentially pumped chambers. The aerodynamic lens acts very much as a conventional lens for photons, but it focuses nanoparticles instead of photons.

Any nanoparticles that can be brought into an aerosol can be studied using the proposed techniques; this includes nanoparticles that can be stored in a liquid solution.

### **Proposed experimental techniques**

We aim to use “standard” spectroscopic techniques, which have been used to study atoms and molecules in gas phase for decades at synchrotrons, to study nanoparticles. Such as X-ray photoelectron spectroscopy, Auger electron spectroscopy, X-ray emission spectroscopy, mass spectroscopy, coincidence techniques etc. These standard types of measurements would give access to species and site specific information (in a highly ordered nanoparticle there is probably site specific information available).

In an ongoing (ANR funded) project (Nano-PLÉADES) at the PLÉIADES beamline at SOLEIL we are aiming at studying isolated nanoparticles using similar techniques as described here. Due to the high performance of the PLÉIADES beamline we feel confident that nanoparticles can initially be studied with soft X-rays at 3<sup>rd</sup> generation synchrotrons. The experience obtained from these initial studies can be used as a springboard to study isolated nanoparticles with a soft X-ray free electron laser radiation as a complementary tool.

### **REFERENCES:**

- [1] Xiaoliang Wang, *Aerodynamic focusing of nanoparticles*, Ph.D. Thesis, University of Minnesota (2006)