"PIERO CALDIROLA" INTERNATIONAL CENTRE FOR THE PROMOTION OF SCIENCE

AND INTERNATIONAL SCHOOL OF PLASMA PHYSICS

INTERNATIONAL WORKSHOP ON

IMAGING

VILLA MONASTERO, VARENNA, ITALY
SEPTEMBER 7-10, 2015

PROGRAMME AND ABSTRACTS

Monday, 7 September

8.15	*Registration*	
09:00	*Welcome*	

FUNDAMENTALS OF EMISSION TOMOGRAPHY IMAGING

09:15	T1.1 - Principles of PET- Part I *(physics/detectors)*	*Alberto Del Guerra*
10:00	T1.2 - Principles of PET- Part II *(simulation/reconstruction)*	*Irene Buvat*
10.45	*Coffee*	
11:15	O1.1 - SPECT1	*Stefaan Vandenberghe*
11.45	O1.2 - Beyond the image	*Isabella Castiglioni*
12.30	*Lunch*	

APPLICATION OF PET EMISSION TOMOGRAPHY IMAGING

14.30	T2.1 - Clinical PET (PET/CT)	*Cristina Messa / Claudio Landoni*
15.15	T2.2 - Preclinical PET	*Rosa Maria Moresco*
16:00	Group photo & *Coffee*	
16.30	O2.1 - PET/US and TOFPET	*Paul Lecoq*
17.00	O2.2 - Optical & Cerenkov	*Antonello E Spinelli*

17:30 POSTER SESSION

18.45 *Welcome Concert & Reception at Villa Cipressi*

Tuesday, 8 September

MRI & Hybrid System

09.00	**O3.1 - Fundamental of MRI**	*AlbertoTorresin*
09:30	**O3.2 - Ultra High field (7T MR)**	*MichelaTosetti*
10:00	**O3.3 - Multiparametric MRI in the musculoskeletal system**	*Luca Sconfienza*
10.30	*Coffee*	
11:00	**T3.1 – Keynote Lecture: Nano- and micro-sized systems for MRI applications**	*Silvio Aime*
11:30	**O3.4 – PET/MR- Part I** *(instrumentation and software)*	*Sibylle Ziegler*
12:00	**O3.5 –PET/MR–Part II** *(Applications)*	*Valentina Garibotto*
12:30	*Lunch*	

Microscopy

14.30	**T4.1 – Keynote lecture: Optical Nanoscopy**	*Paolo Bianchini*
15:15	**T4.2 –Optical Tomography**	*Gianluca Valentini*
16:00	*Coffee*	
16.30	**O2.1 –Non-linear Microscopy in Neurosciences**	*Gian Michele Ratto*
17.00	**O2.2 – Quantitative Phase Microscopy: a label-free imaging tool for clinical applications**	*Pietro Ferraro*

17:50 *Boat trip and banquet dinner*

Wednesday, 9 September

NEUTRON IMAGING

09:00	**T6.1 - Principles of absorption contrast neutron imaging** ***Manuel Morgano***
09:45	**T6.2 - Algorithms** ***Jean Bilheux***
10.30	***Coffee***
11:00	**O6.1 - Imaging with polarized neutrons** ***Indu Dhiman***
11:30	**O6.2 - Imaging of Nuclear Fuel** ***Walter James Williams***
12:00	**O6.3 - Applications to heritage science** ***Robert Erdmann***
12.30	***Lunch***

X-RAY IMAGING

14.30	**T6.1 - Synchrotron based imaging techniques** ***Jean Susini***
15.15	**T6.2 - X-ray imaging at different scale lengths** ***Josef Kaiser***
16:00	***Coffee***
16.30	**O6.3 - Applications to medical imaging** ***Paola Coan***
17.00	**O6.4 - Imaging with inverse Compton scattering X-rays** ***Sandro Donato***

17:30 POSTER SESSION

Thursday, 10 September

Finale

09:00	O7.1&2 - Sparse view CT reconstruction	
		Massimo Nocente
		Muhammad Abir
09:45	O7.3 - Innovative neutron imaging	
		Burkhard Schillinger
10.30	*Coffee*	
11:00	O7.4 Octopus	
		Jelle Vlassenbroeck
11.45	O7.5 Portable X-ray phase contrast tomography	
		Alessandro Olivo
12:30	Final Discussion	
13:00	**Meeting ends**	

Posters

Number	Author	Institution	Title
P.1	W.J. Williams	Idaho National Laboratory, 2525 N Fremont Ave, Idaho Falls, ID 83415	Imaging Techniques Utilized in Post Irradiation Examination of Nuclear Fuel
P.2	T. Minniti	CNR-IPCF, Viale Ferdinando Stagno d'Alcontres, n. 37 - 98158 Messina, Italy	Materials science applications on a new neutron imaging facility IMAT@STFC-ISIS
P.3	H. Akhdar	KSU, Riyadh Saudi Arabia	Development of a high resolution 3D gamma camera
P.4	S. Galib	Department of Mining and Nuclear Engineering, Missouri University of Science and Technology, Rolla, MO 65409	Computer aided detection of oral lesions on CT images
P.5	M. Abir	Idaho National Laboratory, 2525 N Fremont Ave, Idaho Falls, ID 83415	Determination of optimal imaging parameters for the reconstruction of a nuclear fuel assembly using limited angle neutron tomography
P.6	F. Islam	Department of Mining and Nuclear Engineering, Missouri University of Science and Technology, Rolla, MO 65409	Inspection of TRISO fuel coating layer thickness using sparse view CT reconstruction

Number	Author	Institution	Title
P.7	A. Funk	Institute for Complex Materials, IFW Dresden, Helmholtzstraße 20, 01069 Dresden, Germany	An in-situ computed tomography study of the magnetovolume transition in $LaFe_{11.8}Si_{1.2}$
P.8	M. Nocente	Dipartimento di Fisica "G. Occhialini", Università di Milano-Bicocca, Milano, Italy	α particle imaging by gamma-ray measurements along multiple collimated lines of sight in JET deuterium-tritium plasmas
P.9	D. Di Martino	Dipartimento di Fisica "G. Occhialini", Università di Milano-Bicocca, Milano, Italy	Neutron imaging of ancient iron nails
P.10	G. Festa	Dip. Fisica, Università di Roma Tor Vergata, Roma, ITALY	Neutron Resonance Transmission Imaging for 3D elemental mapping
P.11	G. Albani	Dipartimento di Fisica "G. Occhialini", Università di Milano-Bicocca, Milano, Italy	Neutron imaging as a method for diagnosing neutron converters for advanced thermal neutron detectors
P.12	M. Bouzin	Dipartimento di Fisica "G. Occhialini", Università di Milano-Bicocca, Milano, Italy	Reflection image correlation methods applied to gold nanostars slow motions in living cells

Imaging Techniques Utilized in Post Irradiation Examination of Nuclear Fuel

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Keywords: neutron radiography; optical microscopy; computed radiography; tomography, hot cell

Abstract

Idaho National Laboratory (INL) regularly performs post-irradiation examinations (PIE) on various nuclear fuels in order to demonstrate fuel performance under varying operating conditions. Examinations conducted included visual examination, neutron radiography, eddy-current, gamma scanning, profilometry, analytical chemistry, optical and scanning electron microscopy, and micro-hardness testing to determine the material property changes in the fuel and cladding. The conclusions drawn from these examinations are used to verify that the fuel meets the currently established fuel performance requirements for mechanical integrity, geometric stability, and stable and predictable behavior.

Due to the radioactive nature of these fuels, examinations take place remotely in one of the world's largest inert atmosphere hot cells, located at INL's Hot Fuel Examination Facility (HFEF). Equipment used in other industries cannot always survive in this environment and will require modifications even when implementation is possible. Thus, new techniques and equipment are continually being developed to improve the capabilities. Post-irradiation examination is often destructive or time-limited, and as much information as possible must be gained from every examination.

One of the first examinations to take place is neutron radiography. Neutron radiography results aid in the evaluation of the fuel's overall condition, assessment of fuel relocation, and quantification of geometric changes. HFEF is equipped with a 250 kW TRIGA reactor with two neutron beam lines designed specifically for radiography and tomography. One of the neutron imaging facilities has direct access to highly radioactive specimens in the main hot cell and is primarily used for PIE. Information that can be pulled from non-destructive examinations can replace or guide further destructive exams, making neutron radiography on of the most vital techniques in PIE. The current neutron radiography method is the foilfilm transfer technique, where conversion foils (dysprosium and indium) absorb neutrons from the neutron beam that pass through the fuel and become temporarily radioactive in inverse proportion to their absorption in the fuel. The foils are then removed from the beam, and film is placed in contact with the activated foil and exposed to the decay radiation overnight. After this exposure, the film is chemically processed and scanned to produce the final radiographic image. This transfer technique is time consuming, but is one of very few techniques that can provide high-quality radiographic images in a high gamma field. INL is pursuing multiple efforts to advance its neutron imaging capabilities for evaluating irradiated fuel and other applications. These efforts include expanding upon quantitative image analysis and onverting from film to photo-stimulated phosphor plates for neutron computed radiography.

Following the guidance of non-destructive examinations, the fuel is sectioned in chosen areas. These sections are mounted, polished, and transferred to the metallography hot cell for examination. Optical microscopy is performed pre- and post-chemical etching to investigate microstructural changes in the fuel—including grain size, recrystallization, porosity, fission-gas distribution—as well as to define representative regions for SEM and chemical analysis. These exams are unique in their application to radioactive specimens in a sealed, remote-handling environment. This paper outlines the current equipment, methodology, and path forward for post-irradiation imaging with a focus on neutron radiography.

Materials science applications on a new neutron imaging facility IMAT@STFC-ISIS

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Abstract

Neutron imaging can provide two- or three-dimensional, spatially resolved images of the internal structures of bulk samples that are not accessible by other techniques, making it a unique tool with many potential applications. The white-beam conventional attenuation contrast methods are now well established as invaluable non-destructive inspection and quantitative measurement tools. Neutron imaging is similar to x-ray radiography and tomography in that the method produces 2D or 3D attenuation maps. However, the images often produce complementary information due to the differences between x-ray and neutron interaction mechanisms with matter.

For some applications it can be useful to carry out neutron radiography or tomography at one specific neutron energy, for an energy band or for a multitude of separate energies (rather than using a white-beam with no energy discrimination) since the attenuation behavior of materials varies with neutron energy. Energy-dependent imaging allows different materials or even different phases of the same material to be distinguished, and can also reveal microstructure properties of materials. At a pulsed neutron source such as ISIS the energies of neutrons are straightforwardly measured via the time-of-flight technique.

A new neutron imaging and diffraction facility, called IMAT is currently under construction at the ISIS pulsed neutron spallation source and will take advantage of these energy-selective imaging techniques. From 2015 the instrument will enable white-beam neutron radiography and tomography as well as energy-dependent neutron imaging. IMAT will offer a spatial resolution down to 50 microns and a field of view of 200 mm^2.

IMAT will enable a broad range of imaging and diffraction applications, covering a range of scientific and technological areas, among them engineering science, earth science, cultural heritage and biomaterials. The capabilities of the new facility will be presented. Radiography and tomography data collected with specially developed neutron imaging cameras as well as neutron diffraction data will be used to highlight specific potential applications on IMAT, among those 3D reconstructions and diffraction analyses of zeolite and carbon nanotube (CNT) sponges.

Development of a high resolution 3D gamma camera

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Abstract

The aim of our project is to develop 3D gamma camera with high position resolution and sensitivity relying on both distance/absorption and Compton scattering techniques and without using any passive collimation. We have chosen to get full benefit of Geant4 features that allow us to construct the needed geometry of our detector, have full control of the incident gamma particles and study the response of the detector in order to test our suggested geometries. We have simulated three different geometries and each configuration was tested with three different scintillation materials (LaBr3, LYSO and CeBr3). We will present the results of the simulation and results of the tests done on the built prototype of the gamma detector.

Computer aided detection of oral lesions on CT images

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Abstract
Oral lesions are important findings on computed tomography (CT) images. In this study, a fully automatic method to detect oral lesions in mandibular region from the dental CT images is proposed. Two methods were developed to recognize two types of lesions, namely (1) Closed boundary (CB) lesions and (2) Bone deformation (BD) lesions, which cover most of the lesion types that can be found on CT images. For the detection of CB lesions, fifteen features were extracted from each initial lesion candidates and multi layer perceptron (MLP) neural network was used to classify suspicious regions. Moreover, BD lesions were detected using a rule based image processing method, where no feature extraction or classification algorithm were used. The results were validated using a CT dataset of 52 patients, where 22 patients had abnormalities and 30 patients were normal. Using non-training dataset, CB detection algorithm yielded 71% sensitivity with 0.31 false positives per patient. Furthermore, BD detection algorithm achieved 100% sensitivity with 0.13 false positives per patient. Results suggest that, the proposed framework, which consists of two methods, has the potential to be used in clinical context, and assist radiologists for better diagnosis.

Determination of optimal imaging parameters for the reconstruction of a nuclear fuel assembly using limited angle neutron tomography

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Keywords: Limited angle tomography, neutron imaging, nuclear fuel assembly, post irradiation examination, reconstruction

Abstract

The core components of nuclear reactors (e.g., fuel assemblies, spacer grids, control rods, etc.) encounter harsh environments due to high temperature, physical stress, and a tremendous level of radiation. The integrity of these elements is crucial for safe operation of nuclear power plants; post irradiation examination (PIE) can reveal information about the integrity of these components. Neutron computed tomography (CT) is one important PIE measurement tool for non-destructively evaluating the structural integrity of these items. CT typically requires many projections to be acquired from different view angles after which a mathematical algorithm is used for image reconstruction. However, when working with heavily irradiated materials and irradiated nuclear fuel, obtaining many projections is laborious and expensive. Image reconstruction from a smaller-number of projections has been explored to achieve faster and more cost-efficient PIE. Classical reconstruction methods (e.g., filtered back projection), unfortunately, do not typically offer stable reconstructions from highly asymmetric, few-projection data set and often create severe streaking artifacts. We propose an iterative reconstruction technique to reconstruct curved, plate-type nuclear fuel assemblies using limited-angle CT. The performance of the proposed method is assessed using simulated data and validated through real projections. We also discuss the systematic strategy towards establishing the conditions of reconstructions and find the optimal imaging parameters for reconstructions of the fuel assemblies from few projections using limited angle CT. Results show that the fuel assembly can be reconstructed using limited angle CT if 36 or more projections are taken from a particular direction with 1° angular increment.

Inspection of TRISO fuel coating layer thickness using sparse view CT reconstruction

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Keywords: TRISO inspection, Computed Tomography, CT reconstruction, Compressed Sensing (CS), Total variation minimization, Regularization, Statistical methods, Iterative reconstruction.

Abstract
Quality control (QC) method for Tri-isotropic (TRISO) fuel manufacturing using micro computed tomography (Micro-CT) is very time consuming due to long acquisition process. For high throughput inspection and cost reduction of the inspection process, a high quality reconstruction from small number of projections is desirable. Classical CT reconstruction algorithms, such as filtered back projection (FBP) often fail to generate quality reconstruction since the fewer projection data creates artifacts and makes the reconstruction procedure unstable. Some iterative approaches can produce good quality reconstruction by reducing the artifacts. The work explores the potential use of CT reconstruction using few projection data. Inspired by compressed sensing (CS) strategy to reconstruct exact object from few projections, we reconstruct attenuation image of the TRISO particle from very few number of projection images. Total variation (TV) based CT image reconstruction has shown the potential of producing accurate reconstructions from sparse-view data. We propose a CS based CT reconstruction method into statistical image reconstruction framework. We incorporate Poisson noise model into the TV regularization with discrepancy principle to select the regularization parameter that yield an optimal reconstruction. We conclude that using only 45 projection images instead of typical 180 projection images, we can reconstruct the attenuation image accurately for measuring the coating layer thicknesses of the TRISO particle.

An in-situ computed tomography study of the magnetovolume transition in $LaFe_{11.8}Si_{1.2}$

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Abstract
First-order transitions in magnetocaloric materials are the source of strong changes in their magnetization and entropy, giving rise to large magnetocaloric effects. These kind of transitions show interesting phenomena, like phase coexistence and thermal arrest. The way each phase nucleates from the other phase is largely unknown at a microscopic level, besides this being important not only from a fundamental point of view, but also for technical aspects like choosing the geometry of the sample or identifying an upper limit for the cycling frequency.
In $La(Fe,Si)_{13}$, an isostructural first-order transition occurs at the critical temperature T_C, which retains the structural symmetry of the crystal but leads to an abrupt increase in the lattice parameter. We apply low-temperature in-situ computed tomography on magnetocaloric $La(Fe,Si)_{13}$ to study the magnetovolume transition as a function of temperature. The in-situ experiments have been carried out at the beamline ID 19 at the ESRF in Grenoble (France). A stream of cold nitrogen gas was used to drive the magnetocaloric material through the phase transition upon cooling. Using this method, we show how the transition proceeds through a small sample of $LaFe_{11.8}Si_{1.2}$ upon cooling by tracking the subvolumes that turn at each temperature step around the critical temperature T_C. We observe that the regions which perform the magnetovolume transition first are determined by the surface morphology, and that there are big differences in the evolution of the phase transition for flat and rough sample regions. These findings connect microstructural aspects of the first-order transition to important properties like hysteresis and kinetics of the phase transition and can therefore help to tailor magnetocaloric materials towards application.

α particle imaging by gamma-ray measurements along multiple collimated lines of sight in JET deuterium-tritium plasmas

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Abstract

α particles are the key players of the thermonuclear fusion reaction chain. They are born in the t(d,n)α fusion reaction and their role is vital in sustaining the fusion process. Since their birth energy at ~3.5 MeV significantly exceeds the typical temperatures of the fuel deuterium and tritium ions (about 20 keV), α particles can transfer their excess energy to the fuel ions by multiple Coulomb collisions, thus maintaining the bulk plasma in a thermonuclear state without need for external auxiliary heating.

In order to measure the profile of the α particles in view of the next deuterium-tritium campaign, a system of 19 collimated lines of sight, known as "neutron camera", is presently under upgrade at JET to also enable γ-ray spectroscopy measurements within the same device. Here α particle diagnostic data are obtained by observations of the characteristic 4.44 MeV gamma-ray peak resulting from the $^{9}Be(\alpha,n)^{12}C^{*}$ reaction in the plasma between α particles and naturally occurring ^{9}Be impurities.

In this work, we discuss the potentials of the JET neutron/γ-ray camera for γ-ray imaging of JET deuterium-tritium plasmas. The capability to appreciate differences in the measured neutron and γ-ray emission profiles assuming typical measurement error bars is discussed, which is of relevance to study the profile of α particles at their birth energy or after a full slowing down period. A generalized Abel inversion method is proposed for tomographic inversion of measured data in order to determine the α particle profile on a poloidal cross section. The method is based on knowledge of the magnetic flux surfaces where plasma parameters are constant and is applied to synthetic gamma-ray camera signals evaluated in detail from a simulation of the full α particle energy distribution for a reference deuterium-tritium discharge. Results obtained from the inversion are compared to the known α particle profile, both in the case of a pure thermal plasma and in the case of neutral beam injection heating, where the fuel ion energy distribution is no more constant on flux surfaces. Artifacts of the reconstructed profiles with respect to true values are discussed and possibilities offered by algorithms for sparse data tomography without prior knowledge of the magnetic flux surfaces are investigated.

Neutron imaging of ancient iron nails

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Abstract

A set of ancient iron nails was studied, dating back to the 1300-1400 AD and coming from Valle delle Forme (Brescia, Northern Italy). In this archaeological site ongoing excavations have given back a smelting plant of iron minerals, a forge for elaboration of semi-finished products, but also an "archaic" blast-furnace, and it could represent the "missing link" testifying the evolution from the bloomer to the blast furnaces techniques in iron production in northern Italy [1,2]. The nails, presenting a heavily corroded surface (see figure 1). have been studied combining different techniques. In order to infer indications on the inner part too, with the benefit of a non-destructive technique, we performed a 3D tomographic neutron study at PSI, with the purpose to outline different morphological and cristallographic structures (see figure 2). Yet, neutron imaging allows a detailed study of the structure of the nails, and the combination with energy selective imaging, when possible, will be of benefit for further non destructive characterization in archaeometallurgy.

Fig.1 (left-side): typical nail sample – Fig. 2 (right-side): example of a neutron tomograph on a couple of iron nails

[1] C. Cucini, M. Tizzoni, "La Valle delle Forme: i forni e le forge di epoca Bassomedievale", La Miniera Perduta, 1999, pp 201 - 214.
[2] C. Cucini, "Il maglio, la fucina, i forni e il pestaloppe della Valle delle Forme (Bienno, Brescia)", Notizie Archeologiche Bergomensi 16, 227-248 (2008).

Neutron Resonance Transmission Imaging for 3D elemental mapping

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Abstract

Neutrons have been widely applied in archaeometric research, where non-destructive or non-invasive analysis are mandatory. A recent application concerns neutron resonances that can be used as fingerprints to identify and quantify elements within the bulk of different objects. Indeed, Neutron Resonance Transmission Imaging (NRTI) has been successfully applied to the 3D elemental mapping of archaeological samples [1].

The three-dimensional elemental imaging was obtained by NRT. A dedicated set-up at the INES (Italian Neutron Experimental Station) beamline of the ISIS spallation neutron source was used for the experiments [2,3]. Transmission spectra were obtained by measurement of the flight time of epithermal neutrons passing through the sample, an early mediaeval disk fibula [4] from the Hungarian National Museum in Budapest.

The methodology and analysis procedures used in the reconstruction of the 3D NRT elemental image will be described. Further applications and improvements will be discussed.

REFERENCES

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Neutron imaging as a method for diagnosing neutron converters for advanced thermal neutron detectors

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Abstract
Due to the well-known problem of ^{3}He shortage, a series of different thermal neutron detectors alternative to helium tubes are being developed in facilities and laboratories all over the world. Among others, Gas Electron Multiplier (GEM)-based detectors have the advantage of a very high rate capability (MHz/mm^2), and time resolution (around 5 ns), both characteristics being very important for TOF applications. Moreover, they can be realized in relatively large dimensions with a very narrow space resolution (50 µm), thus being also potentially well adapted to monitoring and transmission measurements. However, GEMs are intrinsically charged particles detectors; thus they must be equipped with a neutron converter, for instance $_{10}B$. The thickness, concentration and uniformity of the converter deposit is crucial in determining the detector efficiency and other characteristics. While the determination of such parameters is relatively straightforward for standard (flat) GEM cathodes, this may not be the case for complex, so-called 3-dimensional cathodes (3DC, the latter necessary to improve the performances of the GEM as a neutron detector). In this work we present a method for the estimation of neutron converter deposit on 3DC through neutron imaging. The investigated 3DC is a Al_2O_3 structure with $_{10}B_4C$ coating being developed by CNR-IFP and UNIMIB, whose complex shape poses several complications in terms of modeling and performance assessment. The measurements have been performed at the ROTAX beamline at ISIS, making use of the new imaging system being developed by CNR-IPCF for the next IMAT beamline. Data treatments considering both the white-spectrum and mono-energetic measurements is described and validated through the use of standard reference samples.

Reflection image correlation methods applied to gold nanostars slow motions in living cells

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Abstract
Nanoparticles detection in living cells is a main issue when protocols for drugs delivery or photothermal treatments have to be established. Asymmetric Gold NanoParticles (GNPs), such as nanostars, are endowed of the peculiar characteristic of a strong luminescence in the visible range upon two-photon excitation. However, it should be advisable to be able to detect the nanoparticles also by conventional confocal microscopy. To this aim, we exploit the large scattering cross section of metal NPs to obtain images in reflected light.

In particular, in this study we show that the scattering signal can be used to investigate the dynamics of NPs in cells by acquiring temporal stacks of images that can be correlated pixel-by-pixel. The employed gold nanostars (30 nm average radius), incubated for 4 hours in HeLa cells and internalized through endocytosis, show a slow dynamics with characteristic times in the range of tens to hundreds of seconds. A characteristic time map can be obtained of the whole cell from the temporal behavior of the autocorrelation function once the signal due to the immobile fraction has been subtracted.

Moreover, by building the Spatio-Temporal Image Correlation (STICS) map, it is possible to distinguish free diffusion from active transport, which produces an anomalous displacement of the peak of the 2D correlation function identifying the (endocytotic) vesicle under study. In comparison, a Single Particle Tracking analysis confirms the heterogeneity of the cell cytoplasm, suggesting that a more complex model, such as an intermittent transport or Lévy flights, should be taken into account to fully explain the data.