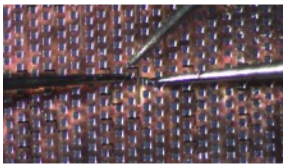
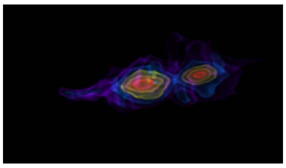
DEPARTMENT OF PHYSICS AND ASTRONOMY "AUGUSTO RIGHI"

Open Physics Hub



ADVANCED SENSING LAB LABORATORY



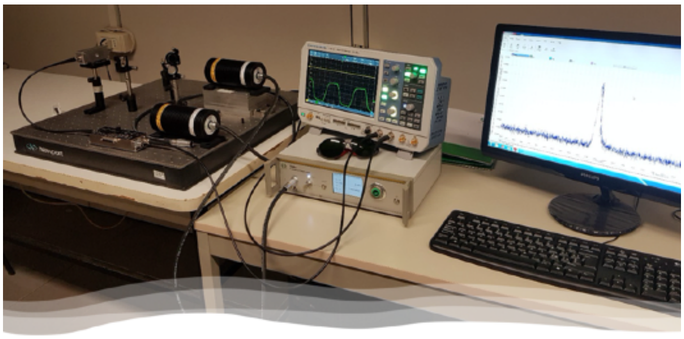
HIGH PERFORMANCE COMPUTING CLUSTER

ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA

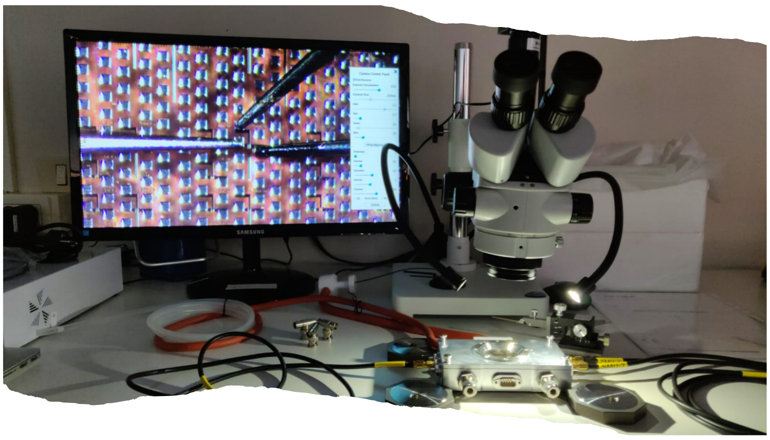
OPH NEWSLETTER

FOCUS

The Advanced Sensing Lab reaches fully operational capability



After less than two years from its approval and funding by UNIBO, both OPH infrastructures are now fully operational. While the HPC cluster has been running at its maximum potential since a few months, the advanced sensing lab has recently completed the installation of its equipments. Located at DIFA - viale Berti Pichat 6/2, room B10/11, B12/13 and A34, the **Advancing Sensing (AS) Lab** consists of several stations to study the response of sensors and detectors to different sources in controlled environmental conditions. In collaboration and with the support of INFN, AS lab features a variety of brand-new advanced instruments (as the laser and the microprobe station, shown in these figures), which are now available for the users of both institutes.



First results are already available. For instance, using the **microprobe station** NEXTRON, equipped with

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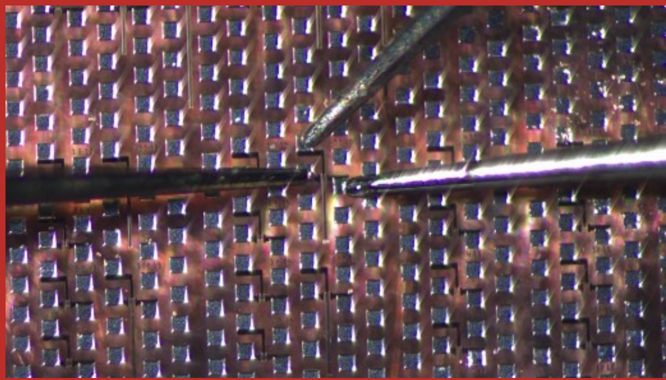
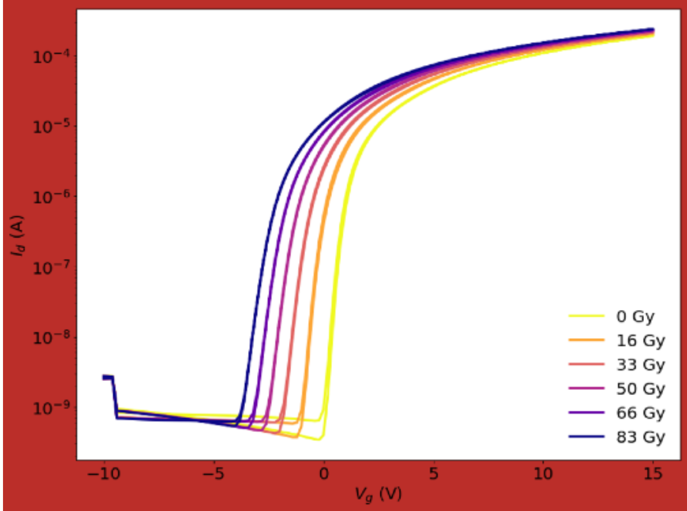
six spring-fixed probes and triaxial cables connection for ultra-low signal measurements (10^{-14} A) and cryogenic system with controlled temperature down to liquid nitrogen (78 K), radiation hardness of oxide thin film transistors is currently being studied. More in detail, source, drain and gate are contacted (pads size of 100 µm, in the figure on the right) with three microprobes, whose alignment is realized with a micropositioner and an optical microscope. In the bottom graph, a transfer characteristics is measured with Dual-channels Source Measure Unit Keithley 2612B under increasing X-ray irradiation dose.

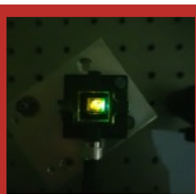
In summary, the excellent features combined with the compact size and limited weight of the microprobe station enable: i) cryogenic (LN) electrical measurement; ii) combination with X-ray station (see below) for ionising radiation experiments; iii) combination with optical station for optoelectronic experiments with lasers; iv) combination with X-Y micropositioner for sample mapping. The other recently completed station is the **picosecond pulsed laser setup** (laser pulse 40ps, maximum pulse frequency 100 MHz, maximum power 7 mW, Picoquant TAIKO controller with laser heads at 375nm and 1060 nm). The system is equipped with a fast and low noise current amplifier FEMTO DHPCA-100 (va-

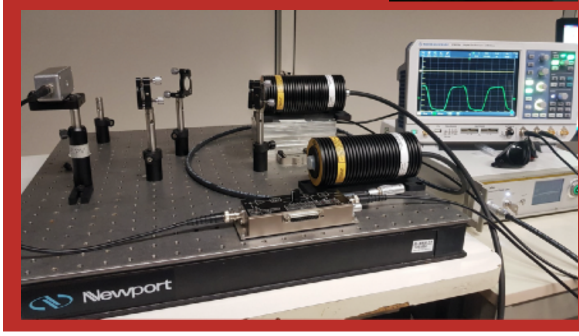
Focus on the microprobe

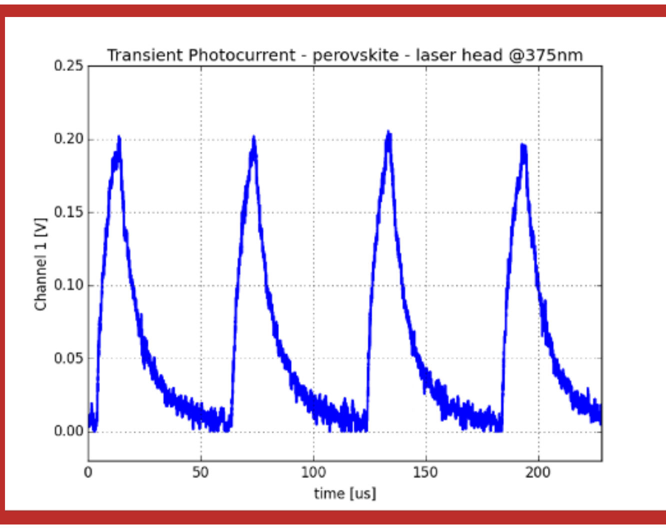




Laser studies







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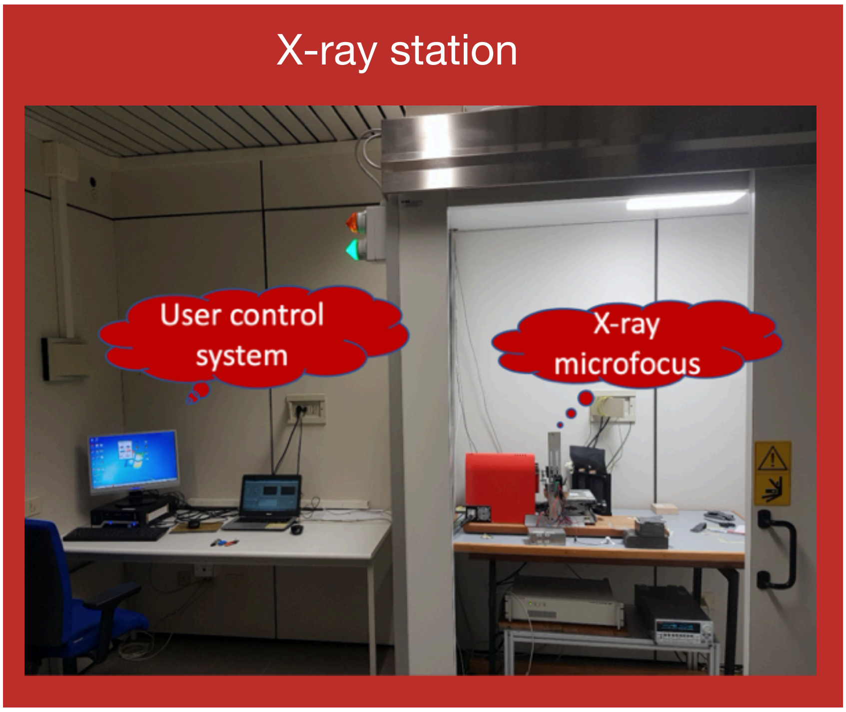
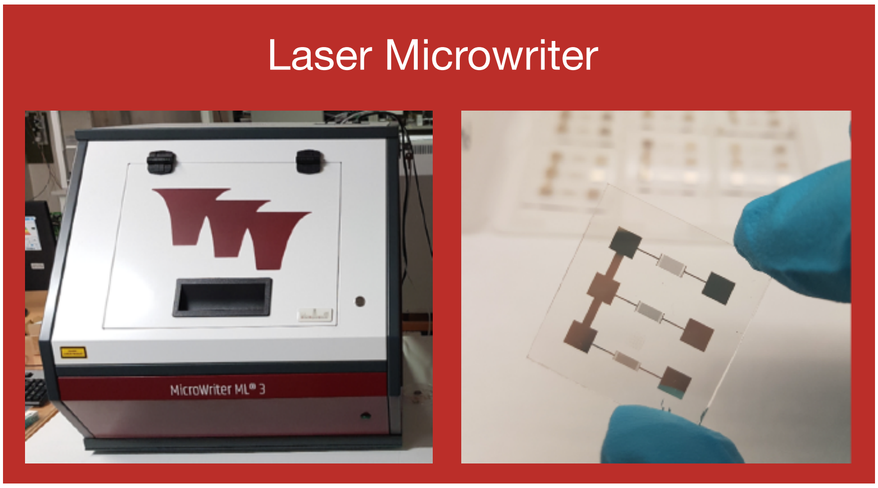
riable gain and up to 200 MHz bandwidth), a UV-Vis spectrometer and a 4-channel 300 MHz oscilloscope RTB2K-COM4. The bottom panel in the previous page shows an example of photo- luminescence and photo- current of perovskite single crystals under 375 nm laser excitation.



The figure on the left shows the X-ray bunker equipped with a Hamamatsu **X-ray microfocus** with custom shutter, tube control unit and a Source Measure Unit for electrical measurements operated by an external user control system.

As already mentioned in the previous OPH newsletter other measurement stations such a time-of-flight station with VME crate, a data acquisition system based on National Instruments PXI modules, a thermal imaging camera (FLIR system) and a climatic chamber are also available, in addition to oscilloscopes, power supplies, function generators, Femto amplifiers, plasma etcher, 3D printer, **laser micro writer** (see figure below)**,** blade coater, MHz current amplifiers and electronic tools are available.



Users may ask for short-period accesses to one of these stations, and for more demanding studies it is possible to combine the available instrumentation and create a more complex measurement station.

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Teaching and outreach

THE DIFA INTERNATIONAL SUMMER SCHOOL ON PHYSICAL SENSING AND PROCESSING

In the context of the DIFA training activities and with the support of OPH, on **July 20th-24th 2020** the Department hosted a new edition of the "**DIFA International Summer School on Physical Sensing and Processing**".

This edition of the school offered a general and broad overview of the various aspects that are involved in the overall pipeline that starts from the **collection of complex and big data**, and goes through data handling/cleaning/curation, **data processing**, **data storage**, and **data analysis** towards the extraction of scientific results and their ultimate communication to the public: all aspects in the School was instantiated in a variety of different physics subdomains, including e.g. High-Energy Physics, Medical Physics, Solid State Physics, Astronomy (Astroparticle Physics). As per its tradition, the School was addressed at Master, PhD students, early-career scientists, but it was also suggested to undergraduate students.

The global health emergency related to the COVID-19 pandemic did not stop the school. Chaired by Prof. Daniele Bonacorsi (with the help of Prof. Nico Lanconelli and Prof. Olivia Levrini), the School changed its original format towards a **completely open and virtual approach**: the School was held 100% online through videoconferencing systems and it was open to anyone interested, with no fees applied. This choice turned a potentially stopping obstacle into a precious opportunity for participating students to get involved in physics training, virtually meet other students and enrich their CV despite the complicated times. The School scored more than 140 participants from United Kingdom, Italy, Spain, Portugal, Germany, France, Netherlands, Sweden, Norway, Brazil, Taiwan, among others. The quality of enthusiasm and interactions among students and teachers was impressive, both online during the discussion and on social media, primarily on Twitter (https://twitter.com/PhysSensProc).

The program of the School was articulated in **front lectures** in the form of **seminars** (1 hour each) - with plenty of additional time for questions and discussions (30 minutes) - and hands-on/tutorial sessions. The School hosted national and international speakers from a variety of Universities and Laboratories worldwide. Dr. Valentin Kuznetsov from Cornell University discussed the state of the art in the complex discipline called Data Science. Jean-Roch Vlimant from Caltech/CERN introduced students to Graph Neural Networks (and beyond) in High-Energy Physics. Piero Altoè from Nvidia gave an overview on Nvidia technologies for accelerating scientific discoveries. Michele Muccini from CNR discussed on advanced sensing based on organic multifunctional materials. A visionary talk on public speaking in science was given by Sergio Bertolucci. Additional seminars were offered by University of Bologna, as well as INFN.

Regarding hands-on activities and tutorials, the participating students had a chance to challenge themselves with a **Data Science hands-on session** with experts from Cornell University, and a Quantum Computing hands-on session with experts from IBM. **Cooperative activities** were held, organised by Prof. Olivia Levrini, to support the creative thinking on the content of the school and the development of transversal, soft and social skills. All attendants to the collaborative activities of the school were granted a certificate of attendance to the School.

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High-Performance Computing, Big Data Analysis

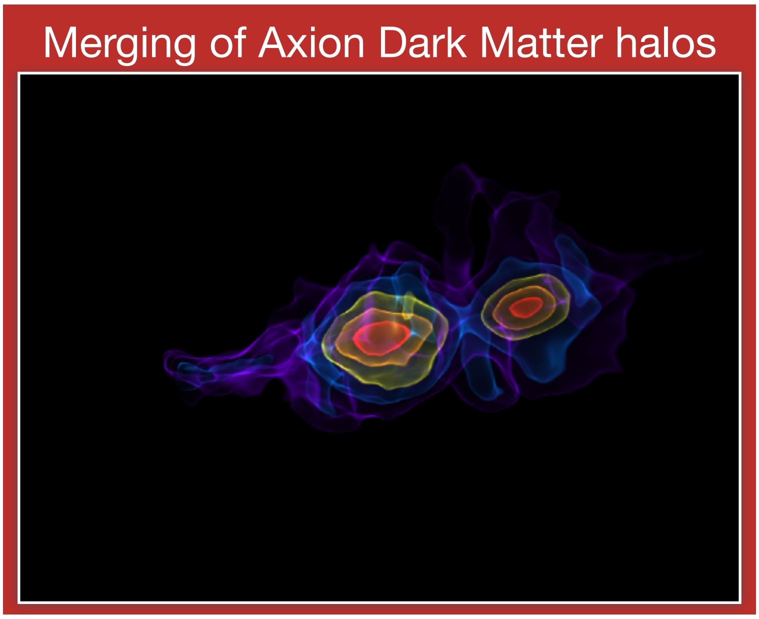
CLUSTER USER GUIDE

The computing cluster is now fully operative, and can be accessed and used by all the members of the Department, after specific authorization provided by the responsible of the Sector. The guide describing its exploitation can be found at this link.

PUBLICATIONS RELATED TO OPH

ULTRA-LIGHT AXIONS SIMULATIONS

About 80% of the mass in the Universe is made of some mysterious **Dark Matter**, invisible to telescopes but clearly revealing its presence through gravitational effects on the motion of visible matter and on the propagation of light. Despite decades of observational attempts, no direct nor indirect detection of a new elementary particle with the features of a possible Dark Matter candidate has been confirmed so far. While this longstanding elusiveness may disfavour the most massive candidates, it has been reviving the interest for lighter particles, as e.g. the so-called **Ultra Light Axions**: scalar particles 30 orders of magnitude lighter than a proton, that could not be detected at colliders but that are expected to leave distinctive fingerprints in the evolution of cosmic structures. An accurate prediction of these observable features can only be achieved through detailed computer simulations of structure formation that consistently take into account the quantum interactions that Ultra Light Axions may exhibit also at astrophysical and cosmological scales.



Unfortunately, standard numerical methods to solve the relevant Schrödinger-Poisson equation have so far been way too computationally demanding to allow simulations of significant volumes of the Universe. To overcome this problem, we have recently developed an **alternative algorithm** based on a **fluid description** of the Axion Dark Matter field that allows a faster solution at intermediate and large scales. One of the characteristic predictions of Axion Dark Matter models is the formation, in the center of Dark Matter halos, of a compact structure with constant density called the "**solitonic core**". By running a set of **high-resolution simulations on the OPH computing cluster BladeRunner**, we have been able to show that the formation and stabilisation of solitonic cores in the center of Dark Matter halos can be achieved also with our fluid-based algorithm. The **figure** shows a 3D rendering of the merging process of two Axion Dark Matter halos simulated with the AX-GADGET code (Nori & Baldi 2018, Nori & Baldi 2021). The red isocontours represent the solitonic cores in the center of each individual halo.

Nori, M. & Baldi, M. (2018) AX-GADGET: a new code for cosmological simulations of Fuzzy Dark Matter and Axion models. *Monthly Notices of the Royal Astronomical Society*, Volume 478, Issue 3, August 2018, Pages 3935–3951, https://doi.org/10.1093/mnras/sty1224.

Nori, M. & Baldi, M. (2021) Scaling relations of fuzzy dark matter haloes – I. Individual systems in their cosmological environment. *Monthly Notices of the Royal Astronomical Society*, Volume 501, Issue 1, February 2021, Pages 1539–1556, https://doi.org/10.1093/mnras/staa3772.

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Useful links

OPH website
https://site.unibo.it/openphysicshub/en/

Department of Physics and Astronomy
https://fisica-astronomia.unibo.it/it

INFN
http://www.bo.infn.it/

CNAF
https://www.cnaf.infn.it/en/

OPH Computing Cluster user guide
https://site.unibo.it/openphysicshub/en/internal

International Summer School on Physical Sensing and Processing
https://site.unibo.it/school-physical-sensing-and-processing/en

Astronomy Public Conferences
https://www.oas.inaf.it/it/conferenze-specola/

OPH Newsletter: previous numbers
#1_ https://apps.difa.unibo.it/files/people/Str957-cluster/OPH/OPH_Newsletter_01_-May2020.pdf

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