Leibniz Institute for Astrophysics Potsdam (AIP)

History

- Initiated in 1700
- The monopoly on calculating the national calendar had provided funding for an observatory
- The Berlin Observatory came to worldwide acclaim when Johann Gottfried Galle and Heinrich Louis d'Arrest discovered the planet Neptune in 1846
- The chosen site of the observatory was a hill south of Potsdam, known as the Telegrafenberg, where a relay station of the optical telegraph system for sending military information from Berlin to Koblenz had stood from 1832 to 1848.
- The Astrophysical Observatory Potsdam was founded on July 1, 1874.
- In 1899, what was then the largest refractor in the world, with 80cm and 50cm lenses,
- Karl Schwarzschild, became director of the observatory. He made fundamental contributions to astrophysics and the general theory of relativity (GTR). Only a few weeks after Einstein's publication, Schwarzschild found the first solution to the highly complicated system of Einstein's equations. Now known as the "Schwarzschild solution," it is of fundamental importance in the theory behind our understanding of black holes.
- In June 1911 the construction of a new observatory began in Babelsberg and on August 2, 1913 the move from Berlin to Babelsberg was completed.
- With the completion of the 122cm telescope, which at that time was the second largest in the world, the Babelsberg Observatory became the best-equipped observatory in Europe. The development of the photoelectric method for investigating weak variable stars and spectroscopic investigations with the 122cm telescope also made the Babelsberg observatory well known outside Europe.
- At the start of 1931, the Sonneberg Observatory, founded by Cuno Hoffmeister, was linked to the Babelsberg Observatory. For more than sixty years it carried out a photographic sky survey, which is the world's second largest archive of astronomical photographic plates.

- With the onset of the fascist regime, the fortunes of astronomy in Potsdam and Babelsberg began to decline. The banishment of Jewish workers played an essential role in this process. The outbreak of the Second World War resulted in almost complete cessation of astronomical research.
- Making a new start after the war was very difficult. In Potsdam, the Einstein Tower had suffered heavy bomb damage. In Babelsberg, valuable instruments, including the 122cm telescope, had been dismounted and sent to the Soviet Union as war reparations.
- In January 1947, the German Academy of Sciences took the Astrophysical Observatory Potsdam and the Babelsberg Observatory under its administration
- The scientific work of the Central Institute of Astrophysics suffered greatly due to the isolation of the GDR from the western world. It was very difficult to make contact with western colleagues. When the Wall was demolished in the autumn of 1989, new possibilities immediately arose.
- On the basis of the prescriptions of the Unification Treaty for the GDR's Academy of Sciences, the Central Institute of Astrophysics was dissolved on December 31, 1991. At the recommendation of the German Council of Science and Humanities, the Astrophysical Institute Potsdam was founded and became part of the "Bund-Länder-Förderung" (today's Leibniz Association) on January 1, 1992.
- In April 2011 the AIP was renamed as "Leibniz Institute for Astrophysics Potsdam (AIP)". Today 200 people work at the research facilities in Potsdam Babelsberg.

innoFSPEC

- The Innovation Centre innoFSPEC Potsdam uses photonics, with a focus on optical fibres and a creative combination of astrophysics and physical chemistry.
- innoFSPEC is a joint centre of the Leibniz Institute for Astrophysics Potsdam and the Physical Chemistry department of the University of Potsdam.
- From molecules to galaxies – the motto of innoFSPEC.
- Under the motto "from molecules to galaxies", innoFSPEC Potsdam was founded in 2008 as a joint project of the University of Potsdam (UP) and the Leibniz Institute for Astrophysics Potsdam (AIP) to establish interdisciplinary research between astrophysics and physical chemistry with international appeal at the Potsdam location.

Astrophotonics (AP)

- One of the problems of contemporary astronomical instrumentation is the economical and structural sustainability of conventional bulk optic instrumentation in the coming era of extremely large telescopes. Massive increase of the size, mass and cost of the instruments which may overwhelm the cost of the telescope itself.
- Astrophotonics could provide a solution to this vicious circle by providing miniaturized, light-weight components based on advanced micro-optics and laser technologies (photonics).
- Multi-object spectrographs exploiting optical fibers are currently able to observe 100's of astronomical objects simultaneously, allowing large surveys of stars and galaxies in our universe.
- Astronomical interferometry based on integrated optics, phase mask coronagraphs, or laser frequency combs for ultra-precise calibration of high resolution spectrographs.
- The project "Integrated Astrophotonics" at innoFSPEC aims at a comprehensive investigation of application of integrated optics to astrophotonics
- Research activties:
    - Discrete beam combiner: three-dimensional integrated-optics beam combiners for infrared stellar interferometry.
    - Optical Frequency Combs: Optical frequency combs (OFC) are light sources consisting of a regular array of narrow spectral lines.
    - AO-assisted Astrophotonics
      Arrayed Waveguide Grating and Echelle Gratings: Integrated spectrometers on the basis of AWGs and photonic Echelle gratings.
    - Fibre Bragg Gratings

Applied Analytical Photonics (AAP)

- Development of fibre-optical photonic components and their combination for spectroscopy and sensing in the processing industry and in its related research
- AAP aims at the implementation of novel fibre-optical photonic tools for the analytical characterization of chemical, physical, or biotechnological processes in liquid dispersions.

Multi-Channel Spectroscopy (VKS)

The Multi-Channel Spectroscopy group is specialised in optical fibres and integrated optic waveguide devices. The group primarily targets applications on spectroscopy for astronomy to further expand the capabilities of multiplexed fiber-based spectroscopy in astronomy, as well as for interdisciplinary approaches and technology transfer.

Hybrid Nanostructures (HNS)

In our research we combine different methods from DNA nanotechnology, optical spectroscopy and scanning probe microscopy in order to study physic7o-chemical processes up to the single-molecule level. A major focus is on the exploitation of DNA nanotechnology to assemble functional entities with nanometer precision.

Optical Materials (OM)

The focus of the research team 'Optical Materials' is on the development of photonic nanomaterials using bottom-up strategies. For this purpose nanoscale building blocks are wet-chemically synthesized and subsequently self-assembled into functional devices.

Ongoing projects of the astrophotonics section of innoFSPEC

MARCOT

- Multi-Array of Combined Telescopes (MARCOT), a modular astronomical infrastructure facility for high resolution spectroscopy and large field of view
- The primary objective of the MARCOT Project is to carry out the conceptual design and establish a plan for the construction of a new European telescope concept with a large effective aperture and low cost.
- The idea consists of the combination of multiple identical optical elements resulting in a new infrastructure facility with a large effective aperture. The photons are collected by individual optical fibers attached to each optical assembly, which are finally combined by a novel multimode photonic lantern into a single fiber, which feeds a high-resolution spectrograph

- This technique would allow the development of the next generation of very large effective-aperture telescopes with substantially reduced budget, serving two main purposes: high-resolution spectroscopy and large field of view seeing-limited high dynamic range imaging, also capable of achieving very fast cadences. Due to the low cost, the ability to replace individual (or all the) mirrors with an improved version, or with different specifications in the future, gives this technique flexibility to adapt with technological advances.

POCO

Potsdam frequency comb, POCO, (Spanish for "little bit") is a turn-key instrument designed and developed by innoFSPEC that uses specially designed micro-ring resonators to generate ultra-stable comb lines for calibration of astronomical spectrographs

OH-SUPER

- A serious problem for ground-based NIR astronomy consists in the presence of a large number of strong hydroxyl (OH) emission lines originating in the earth's atmosphere.
- FBGs offer excellent properties to filter out the OH emission lines. However, using an array of simple FBGs will result in high losses. An extension to simple FBGs are aperiodic FBGs (AFBGs). A single AFBG can provide as many as 100 notches to filter out the NIR OH emission lines.

Telescope Beam Combiners

- At the heart of ESO GRAVITY instrument lies a 2D integrated optics device that combines light from 4 telescopes in K-band.
- The 3D discrete beam combiners (DBC) allows a straightforward scaling to larger arrays of telescopes by simply extending the number of waveguides in the array.
- With the new state-of-the-art fully automated ultrafast laser inscription facility of Astrophotonics group, complex 3D waveguide structures can be inscribed in glass.

Adpatative Optics

The most direct approach consists in actively correcting for the distortion of the spatial coherence of starlight. This is already possible thanks to adaptive optics, a technique using a deformable mirror to correct distortions in real time and focus the starlight town to the diffraction limit. This approach is however a very expensive and complex one, especially for very large telescopes. A photonic solution to this problem is use a photonic lantern to distribute the light collected by a multimode fiber placed at the focus of the telescope into several single-mode fibers outputs.

Photonic Lanterns

Photonic lanterns (PL) are photonic (or fibre optic) devices that distribute the light collected by a large multimode waveguide (or optical fibre) into multiple near diffraction-limited waveguides (or single-mode fibres). In astrophotonics, such devices are crucial to couple star light efficiently from a telescope into photonic components.

The most important achievements

- These somewhat unwieldy terms can be summarised in a short sentence: the development of a spectrograph 'on-a-chip'. This picture gives an idea of what is involved: the realisation of what are traditionally large and expensive high-performance optics in a tiny photonic chip.
- The Leibniz Institute for Innovative Microelectronics (IHP) has all the prerequisites and expertise to integrate the image sensor into the PIC, a marriage of photonics and electronics, so to speak.
- Researchers hope that this will not only lead to a breakthrough for astrophysical instruments, particularly in space, but also to outstanding innovation potential and future market opportunities in areas such as agricultural technology, mobility, healthcare, food technology and chemistry

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Photon Density Wave (PDW) Spectroscopy

PWD is an advanced optical technique used to probe the properties of turbid media, such as biological tissues, where light scattering dominates. It relies on the propagation of photon density waves, which are generated when a modulated light source interacts with the medium.

Center for High Angular Resolution Astronomy

The flagship project of Georgia State University's Center for High Angular Resolution Astronomy (CHARA) is its optical interferometric array of six telescopes located on Mount Wilson, California. Each telescope of the CHARA Array has a light-collecting mirror 1-meter in diameter. The telescopes are dispersed over the mountain to provide a two-dimensional layout that provides the resolving capability (but not the light collecting ability!) of a single telescope with a diameter of 330 meters (one fifth of a mile)! Light from the individual telescopes is transported through vacuum tubes to a central Beam Synthesis Facility in which the six beams are combined together. When the paths of the individual beams are matched to an accuracy of less than one micron, after the light traverses distances of hundreds of meters, the Array then acts like a single coherent telescope for the purposes of achieving exceptionally high angular resolution. The Array is capable of resolving details as small as 200 micro-arcseconds, equivalent to the angular size of a nickel seen from a distance of 10,000 miles. In terms of the number and size of its individual telescopes, its ability to operate at visible and near infrared wavelengths, and its longest baselines of 330 meters, the CHARA Array is arguably the most powerful instrument of its kind in the world.

The CHARA Array Integrated Optics Testbed or CHARIOT

The goal of the CHara ARray Integrated Optics Testbench (CHARIOT) is to establish a fully characterized (nulling) interferometry setup for on-sky tests of novel astrophotonic 2D or 3D beam combiners for the interferometry community worldwide. CHARIOT is planned for four telescope beams covering the J-, H-, and K-bands with plug-and-play fiber interfaces. Verifying novel astrophotonics on-sky with CHARIOT will enable the development of components and advances in instruments in many fields, including nulling and spectro-interferometry.

Related links

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