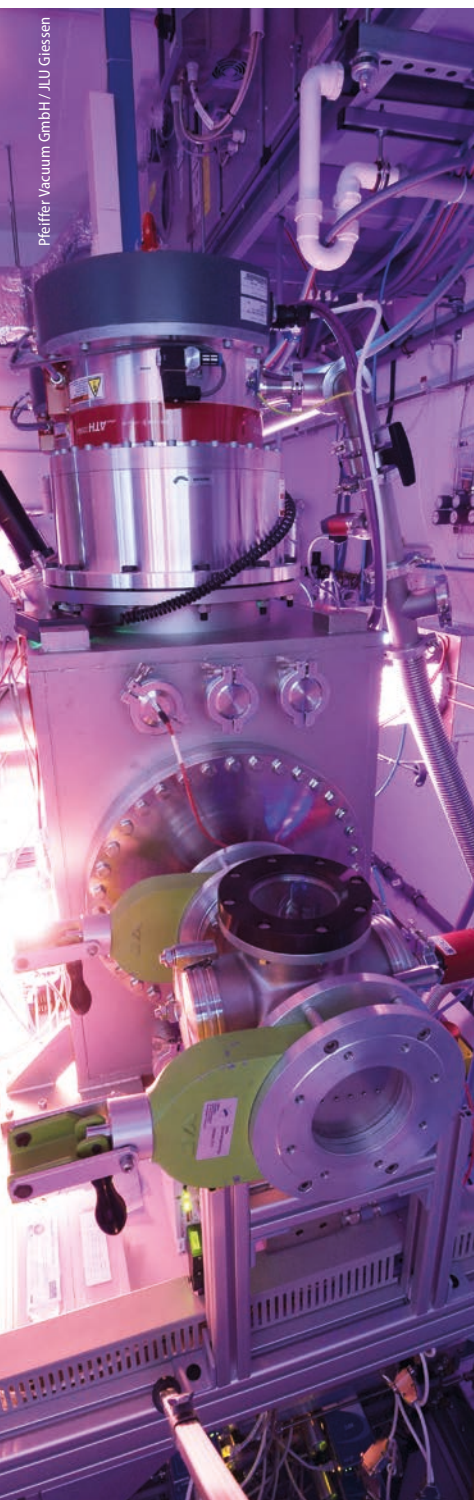


## Space research on Earth

New satellite propulsion systems for use in space are being tested at Justus Liebig University Giessen with the aid of vacuum technology.



**B**efore satellites are launched into space or a space mission commences, numerous tests have to be carried out. These tests are designed to check and ensure proper functioning in space and can only be carried out on Earth with the aid of vacuum technology. Space research has been taking place at Justus Liebig University Giessen (JLU) since the 1960s, and vacuum equipment from Pfeiffer Vacuum has been part of this from the very beginning. Today, industrial partners and space agencies test their engines under space conditions in the research group of Peter J. Klar, Executive Director of the Institute of Experimental Physics I at JLU.

### Ion thrusters: From a gimmick to an enabling technology

Before “New Space”, industry still regarded electric space propulsion systems as a technical gimmick that could possibly be used one day on a scientific mission. So, the field was left to university research, with a greater or lesser degree of financial commitment from industry. Today, electric space propulsion systems are regarded as “game changers”, since completely different missions can be carried out in space with these than with purely chemical propulsion systems.

The 2DIBS facility with several RF ion sources for coating substrates on both sides uses ion beam sputter deposition. This system is also equipped with two turbopumps of the type ATH3204M with ACP 28 backing pumps.

At the Institute of Experimental Physics I, there are many large experimental facilities for materials research and space physics. The facilities include large vacuum chambers, in which ion thrusters can be studied in operation. These are so-called space simulation facilities. A vacuum is created in the chambers and the thrusters are tested and measured inside them (Fig. 1). Traditionally, the group at JLU concentrates on the development of electric space propulsion systems.

There are various types of those systems. The radio frequency ion thruster (RIT) thrusters developed by Prof. Dr. Horst Löb, also based in Giessen, in the 1960s have a hemispherical discharge chamber in which a plasma is ignited from the gaseous propellant. The open side of the discharge chamber is separated from space by a grid system. During thruster operation, charged propellant ions are accelerated out of the plasma and away from the thruster by the electric field applied between the grids and thus generate thrust according to the recoil principle.

To prevent the spacecraft from becoming electrically charged, the positively charged ion plume must be neutralized with electrons. In the pioneering days, mercury vapor was employed as the propellant, but today the xenon is generally used. Since this is a scarce resource, however, alternatives are being sought.

### New test facilities

The electric propulsion group at JLU is striving to develop novel standardized test procedures. With the commercialization of the

technology, the tasks of university groups are changing. The goal is not to build large quantities of ISO 9000 certified thrusters. For this reason, the group is concentrating on the development of new types of test equipment, which requires vacuum technology. The group is also focusing on concepts for better thruster diagnostics and new types of miniaturized thrusters for very small satellites. The fabrication of such thrusters uses micro- and nanostructuring methods.

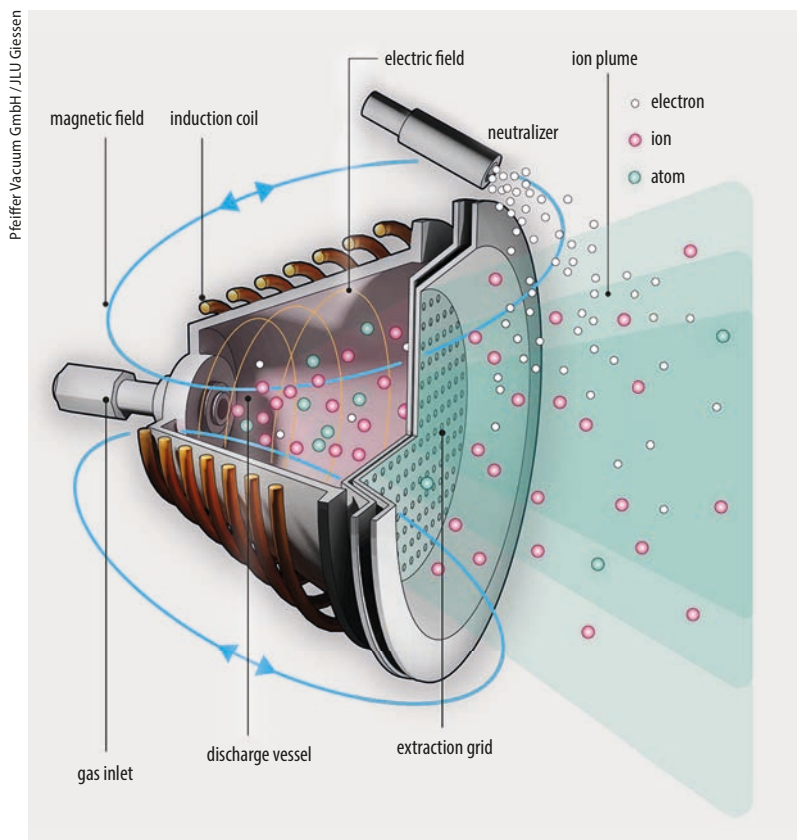
JLU is currently setting up new, unique test facilities, to investigate the electromagnetic compatibility (EMC) of electric space propulsion systems. Here, tests will be carried out to determine whether the electromagnetic radiation emitted by

the thruster during operation interferes with other electronics. The phenomenon is comparable to the disturbance in reception of an analog radio in a car when driving past high-voltage power lines.

Such tests are important if you want to operate satellites with such thrusters, because this kind of interference can, in the worst case, lead to the complete loss of the satellite. The EMC test facilities for testing operating thrusters must be set up quite differently to those used for standard electronics. Since the thrusters need space conditions, i. e. vacuum, to operate, either the EMC measurement must be carried out in the vacuum tank itself, or a vacuum tank must protrude into the shielded EMC measurement cabin.

In addition to these new facilities, the old centerpiece of Giessen's electric propulsion research, namely the JUMBO test facility, is still in operation. It was commissioned back in the 1970s to cooperate with industry in testing radio frequency ion thrusters for use in space and was one of the first and for some period one of the largest in the world. In the meantime, many facilities have been built, including much larger ones. The JUMBO has served as a model for many of those. There are hopes to have similar success in the future with the new EMC facilities. The vacuum pump infrastructure of such facilities needs to be very sophisticated. The aim is to create operating conditions that are as close as possible to those in space, because the background pressure in the vacuum chamber also determines the performance of the thruster and, after all, one wants to know how the thruster will perform in space – and not in a poor vacuum.

In the field of space travel research, the scientists at JLU are working on new types of materials that are tailored to the extreme requirements in space. Examples are GaN semiconductor structures for radiation-hard electronics. The radiation hardness can also be investigated in special test facilities at JLU and its partner institutions, whereby the semiconductors are bombarded with high-energy gamma radiation or particle radiation. Furthermore, RF ion sources like radio frequency ion thrusters are also used in material processing, for ion beam etching or in ion beam sputter deposition, for example.



**Fig. 1** A low-temperature plasma of the gaseous propellant burns in the discharge chamber of the radio- or high-frequency ion thruster. The plasma is maintained by the alternating magnetic fields of a coil operating in the MHz range. The ions of the plasma are extracted by the grid system and accelerated to energies of about 1000 eV. Electrons from the neutralizer neutralize the positively charged ion beam. The Giessen RF ion sources for materials processing work on the same principle.

## Vacuum is essential

Vacuum technology plays an important role in this research. All the research areas run experimental facilities that have to be operated under high vacuum or even ultra-high

vacuum. This applies just as much to materials research as to space research. Various turbopump and backing pump systems from almost the entire Pfeiffer Vacuum product range are in use here, including turbopumps from the HiPace and ATH series and rotary vane pumps from the DuoLine. Magnetic bearings and corrosion protection are important features.

Another benefit is the particularly long service life of the turbopumps. In addition to the vacuum pumps themselves, the group purchased various vacuum components, such as vacuum gauges, corrugated hoses, seals and connecting elements. The fast availability and delivery of the goods are a clear advantage.

Close relationships enable scientific exchange and discussion of scientific issues in a productive way. This is necessary, because every new system that is designed, build and operated has different requirements

and poses different challenges. For example, there are systems that require very clean vacuum, where all the pumps need to be operated without lubricants, if possible.

Some systems work with corrosive gases such as iodine. Iodine is currently being investigated as an alternative to xenon as a propellant for ion thrusters. Here, the Giessen scientists use the HiPace 1500C in combination with the Duo 35 MC two-stage rotary vane pump. Both pumps are designed to be resistant to corrosive gas, so that the longest possible service life guaranteed.

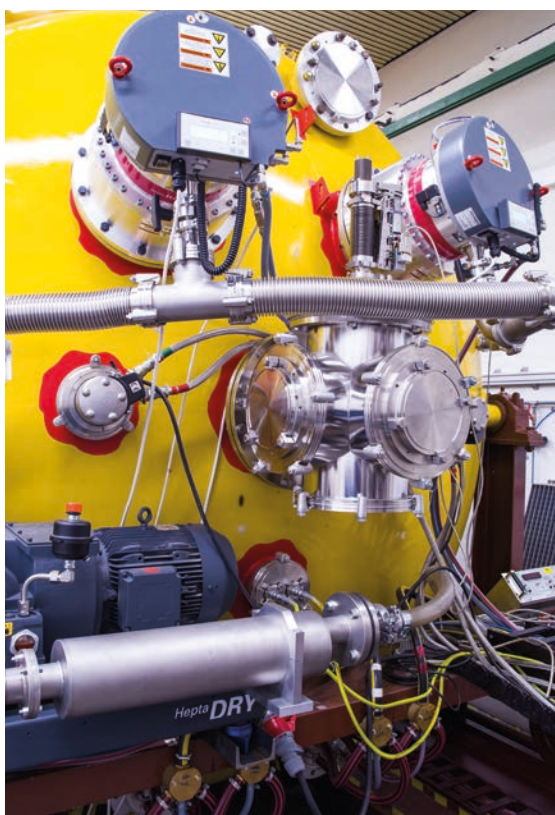
### From Giessen into space

Since 2017, Justus Liebig University Giessen has been offering the degree program “Physics and Technology for Space Applications”. This interdisciplinary degree program combines physics and electrical engineering. It is tailored to the needs of the space industry, which

have changed drastically, due to the transformation from Old Space to New Space. The classical aerospace degree programs in Germany are hosted in the field of mechanical engineering. Electric space propulsion systems such as the RIT technology, are rapidly gaining importance at present, and their operation and integration on satellites requires sound knowledge of physics and electrical engineering.

But the degree program not only addresses electric space propulsion systems, but also provides a broad introduction to space travel. This includes mission planning and upcoming missions, spacecraft, various propulsion technologies, experiments at the International Space Station and much more. Vacuum technology plays an important role here. With a sound basic knowledge of physics and electrical engineering, graduates have excellent career opportunities, not only in the field of space travel.

Pfeiffer Vacuum GmbH / JLU Giessen



Two ATH 3204M turbopumps with a Hepta Dry 200 screw pump as a backing pump at the JUMBO space simulation facility for testing ion thrusters. In combination with two HiPace 2300s with Duo 65 backing pumps and eight cryo pumps, a pumping speed of 150,000 liters of Xe per second is achieved.

## Contact

**Pfeiffer Vacuum GmbH**  
Berliner Straße 43, 35614 Asslar  
[www.pfeiffer-vacuum.com](http://www.pfeiffer-vacuum.com)