

# Internationalized and research-oriented photonics education – Abbe School of Photonics

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## ABSTRACT

The Abbe School of Photonics (ASP) provides and coordinates the optics and photonics education of graduate and doctoral students at the Friedrich Schiller University in Jena, Germany. The internationalized Master's degree program is the key activity in training students in the optical sciences. The program is designed to provide them with the skills necessary to fill challenging positions in industry and academia. Here, an essential factor is ASP's close collaboration with more than 20 German photonics companies. To sustain these partners' future economic development, the availability of highly qualified employees is constantly required. Accordingly, these industrial partners, the European Union, the local state and the federal German government are strongly involved in the sustainable development of ASP's curriculum by both conceptual and financial engagements. The main goal is to promote the students' academic careers and job experience in the photonics industry as well as in academia. To open up the program to students from all over the world, all ASP lectures and courses are taught in English. Since 2009, more than 250 graduate students from more than 40 different countries have been enrolled at the School. Almost 90% of them of non-German nationality, fulfilling the essential ASP philosophy to locally establish an international education program. ASP's qualification strategy is fully research-oriented and based on the principles of academic freedom, competitive research conditions and internationalization at all levels. The education program is complemented by a structured doctoral student support and a prestigious guest professorship program.

**Keywords:** Photonics, optics, Master degree, doctoral studies, industry support, internationalization

## 1. INTRODUCTION – UNIFYING RESEARCH AND EDUCATION

In Jena, the roots for an exceptional scientific community specializing in optics and photonics were laid by the breakthrough works of Ernst Abbe, Carl Zeiss and Otto Schott in the late 19<sup>th</sup> century, rendering Jena the “cradle of modern optics”. Due to this tradition, the Friedrich Schiller University Jena has a strong focus on photonics, which nowadays is concentrated in its interfaculty center Abbe Center of Photonics (ACP). This center hosts the research and education activities on optics and photonics of the university and incorporates major contributions from Jena's non-university optical research institutes and photonics industry. Counting more than 40 faculty members from physics, chemistry, biology and medicine, ACP shapes the future of the local photonics community by serving as lead partner in multiple collaborative research and education projects of national and international priority. ACP's research covers fundamental and applied topics and generates annually about 450 publications in peer-reviewed international journals. However, the main goal is to produce synergetic effects between ACP's research institutes, its industrial partners, and its multiple international collaborators in order to enable a scientific and economical added-value. This goal is explicitly focused both in research and education, which are inseparably cross-linked (see Figure 1).

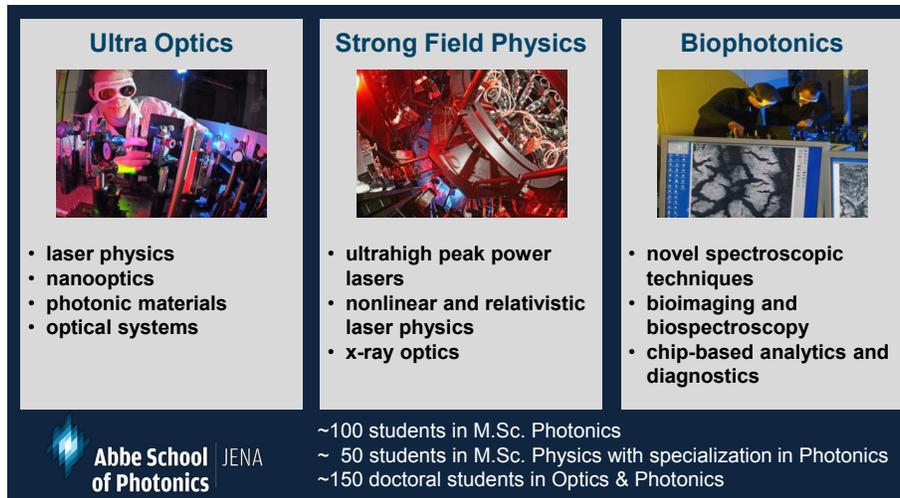


Figure 1. Areas of research at the Abbe Center of Photonics and cross-linking photonics education at the Abbe School of Photonics.

By its integrated Abbe School of Photonics (ASP), the center provides high-level training of young scientists during all qualification phases, promoting their careers in academia and photonics industry. ASP's concept and philosophy aim at establishing Jena as one of Europe's leading educational centers in optics and photonics. ASP was shaped from the traditionally established, broad spectrum of teaching and research activities in light sciences at the Friedrich Schiller University Jena. The School offers outstanding opportunities for high levels of qualification at the undergraduate and graduate levels in the subjects of optics and photonics. The underlying qualification strategy is fully research-oriented and based on the principles of academic freedom, competitive research conditions and internationalization at all levels of education and research. On the one hand, ASP's training promotes and links career phases of young scientists in academia. On the other hand, the School strongly recognizes its responsibility that the majority of its graduates will continue a career in research-intensive companies. All of our competitive career development measures are therefore designed to lay the foundation for successful careers in academia and industry.

The School was founded in 2008 following a competitive call by the local state and the German federal government. Since then, these governmental bodies, together with Germany's photonics industry and the European Union, provided competitive financial support necessary to support this process. The close collaboration with industrial partners is one key factor of ASP's education program. To sustain these partners' future economic development, all partners are in close contact with the ASP management to secure the availability of highly qualified personnel on the labor market at the right time. The ASP graduates are just the candidates which the German photonics industry is looking for.

## 2. MASTER'S DEGREE PROGRAM

As one of its core activities, with the Master of Science in Photonics (M.Sc. Photonics), ASP offers a two-year Master's degree program whose lectures and courses are taught completely in English. The M.Sc. Photonics is an internationally recognized graduate degree, providing multidisciplinary coverage in the field of optics and photonics, from upstream scientific aspects in engineering and knowledge regarding major areas of business. The recruitment for this program is based on a global strategy to select the best-matching students from around the world. In sync with this undergraduate education program, the School has established a coordinated doctoral program (comparable to a PhD program in the USA) which is merged with the local strategic research programs. Further academic measures and career development work are supported by an advanced, hands-on optics training and a comprehensive scholarship program for deserving Master's degree and doctoral students. Along with its academic course program, ASP organizes and carries out strong joint activities on business-oriented education which are run in collaboration with industrial and other academic partners.

Historically, the ASP Master's degree program is rooted in the European educational system and was funded by the Erasmus Mundus scheme of the European Union since 2009. The course of study was jointly designed and supported by leading centers of optics education in Europe: the Technical University Delft, the Imperial College London, the Université Paris-Sud with its Institut d'Optique, the University of Eastern Finland, and the Warsaw University of Technology. In addition, ASP acquired a transatlantic European mobility program (MILMI – Master International in

Laser, Material Sciences and Interaction) together with the Université Bordeaux, the University of Central Florida, and the Clemson University (South Carolina). Based on this truly international experience, and combined with Jena's profound expertise in optics education, the now well-established international Master's degree program provides the students with a solid knowledge in optical science and technology and is well-suited to incorporate students of various professional and socio-cultural backgrounds.

Nowadays, the M.Sc. Photonics program is fully integrated into the study courses of the Friedrich Schiller University Jena. The key enabling infrastructure of the ASP Master's degree program is provided by the scientific and teaching staff of the Faculty of Physics and Astronomy, the Faculty of Chemical and Earth Sciences, and other faculties. These lecturers offer long-standing expertise in optics and photonics education, and our Master's degree program takes full advantage of this fact. At the same time, the program is embedded into the rich research environment of the ACP. Students obtain hands-on experience in methodology courses taking place in research-grade photonics laboratories – accessing various facilities of the university's institutes, the local Fraunhofer Institute for Applied Optics and Precision Engineering, the local Leibniz-Institute of Photonic Technology, the Helmholtz Institute Jena, as well as those of some prominent industrial partners. Master's degree students enrolled at ASP benefit from the strong connections within the German photonics industry and their involvement in our study track. In recent years, ASP's German partner companies were Agilent Technologies, Berliner Glas, Carl Zeiss AG, Jenoptik AG, Karl Storz, Leica, Linos Qioptiq, Lissotschenko Mikrooptik, Nanoplus, Novaled, Osram, Philips, Polytec, Precitec, Rofin, Saueressig, SICK AG, Trumpf, U2T Photonics and Wetzel Holding AG. Every graduate student experiences at least one mandatory internship with a focus on practical training in the application-oriented optics laboratories of these partner companies or at university institutes. Moreover, the final thesis of the Master's degree program can be fully accomplished through the successful completion of an industrial project.

Applying to the M.Sc. Photonics program is facilitated by a convenient online application system. All applicants are evaluated by ASP's selection committee with respect to their academic excellence, their English skills, their expressed intentions to pursue a career in Germany or Europe, and their previous qualifications; the top 50 students are selected to be eligible. In addition, comprehensive financial support is offered to the most excellent students through two-year scholarships funded by the German Federal Ministry of Education and Research (BMBF) and the local state government. Since October 2009, an annual average of 45 students out of about 700 annual applicants has been accepted at ASP. The student numbers with respect to their countries of origin is displayed in Figure 1. Since 2009, a total of 250 graduate students from more than 40 different countries, with the highest numbers from central Asia and central Europe, have been enrolled at the School. Most notably, almost 90% of the graduate students are of non-German nationality. Likewise, the faculty of the School provides the main teaching activities of the Master of Science in Physics (M.Sc. Physics) program, whose students can choose to attend numerous special lectures in photonics. Currently, about 50 M.Sc. Physics with a specialization in photonics are enrolled. While approximately 80% of our graduate students, who successfully finish the program, continue on the academic track, accepting PhD positions at top-ranking universities worldwide, the other alumni regularly find appropriate positions in the photonics industry, strongly represented in Jena and also prevalent throughout Germany.



doctoral students, ASP supervisors, and interested guests. This scheme offers an ideal platform for the students to receive concentrated feedback from fellow students and professors, to possibly shift the student's perspective on their work disclosing formerly disregarded aspects, and to prepare for competitive, demanding on-stage-performances as young academics. The prototypical curriculum performed by an international student, who firstly enters in the M.Sc. Photonics and then successfully accomplishes his or her doctoral studies, is shown in Figure 3.

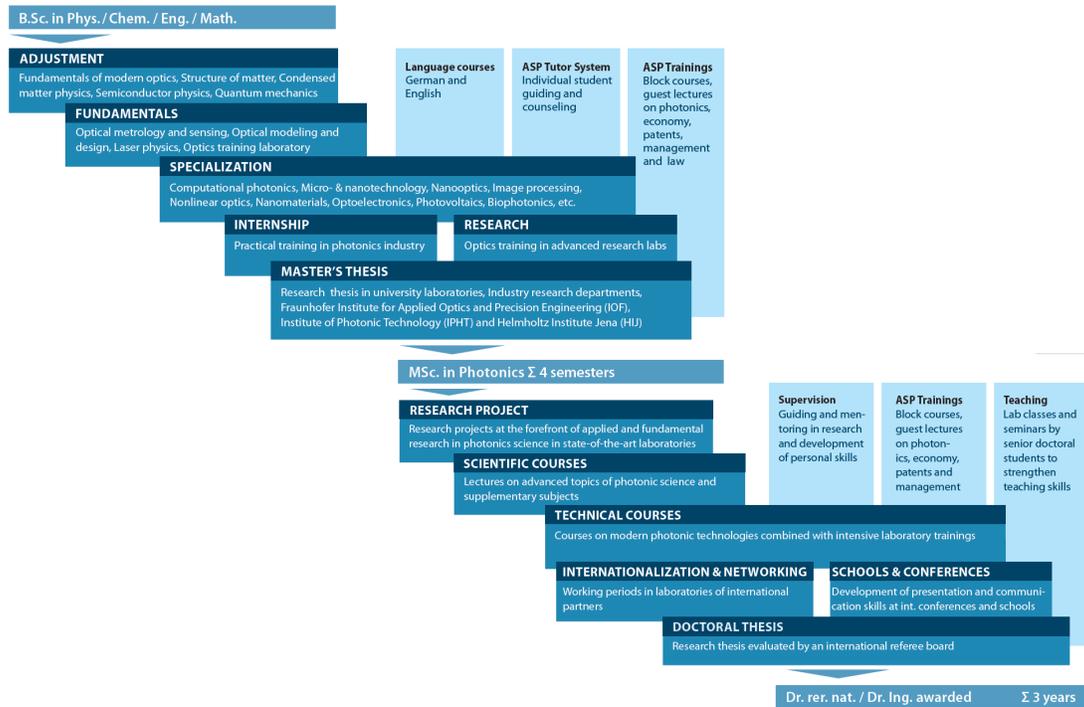


Figure 3. Curriculum of a prototypical two-year M.Sc. Photonics study track, followed by consecutive, three-year doctoral studies at the Abbe School of Photonics.

#### 4. GUEST PROFESSORSHIP PROGRAM

The ASP guest professorship program, firmly established in 2008, has become a truly international brand. To date, the ACP principal scientists and their students have benefitted from special lectures held by more than 40 international experts who have accepted our invitation to lecture in Jena for visits up to three months. Both principal scientists and students have strongly contributed to the educational values of ASP on several levels. First, many ASP guest professors have given regular lectures within the M.Sc. Photonics program. Second, they have shared their perspective and expertise with the doctoral students, ACP principal scientists, and representatives from our industrial partners in devoted special lectures on the most current topics in their research fields. Last but not least, our guest professors have proven to open up an inspiring source of novel ideas for ACP scientists by fruitful and mostly long-term collaborations.

During their local lectures, the ASP guest professors exhibit an ideal opportunity for the M.Sc. Photonics and doctoral students to connect with the global science community. Besides the topical input which all students obtain by attending special lectures held by the guest professors, these distinguished scientists are available for face-to-face discussions in Jena, to share their perspectives and expertise directly with the ASP students.

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