

JEUMICO: Czech-Bavarian astronomical X-ray optics project

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Abstract. Within the project JEUMICO, an acronym for Joint European Mirror Competence, the Aschaffenburg University of Applied Sciences and the Czech Technical University in Prague started a collaboration to develop mirrors for X-ray telescopes. Corresponding mirror segments use substrates of flat silicon wafers which are coated with thin iridium films, as this material is promising high reflectivity in the X-ray range of interest. The sputtering parameters are optimized in the context of the expected reflectivity of the coated X-ray mirrors. In near future measurements of the assembled mirror modules optical performances are planned at an X-ray test facility.

Key words: X-ray telescope – Lobster Eye optic – iridium – sputtering

1. Introduction

In May 2015 the funding agency BAYHOST (an abbreviation for Bavarian Academic Center for Central, Eastern and Southeastern Europe) published a call for proposals on joint Bavarian-Czech projects, based on a joint initiative of the Bavarian State Ministry of Education, Science and Arts and the Ministry of Education, Youth and Sports of the Czech Republic [1]. The political intention of this call was to progressively enhance the scientific cooperation between the Czech Republic and Bavaria. Therefore scientists from both countries have been asked to submit joint applications for bilateral projects. Thereby the program was focused on research and development. For the selected projects financial support was offered to cover travelling costs and to support cooperation activities with special accent to long-lasting effects, bringing together researchers of several academic levels. In addition, support can be granted for workshops and seminars organized by the joint project teams (BAYHOST: Joint Call of the Bavarian State Ministry of Education, Science and Arts and the Ministry of education, Youth and Sports of the Czech Republic for joint projects 2016-2017, 2015).

Scientist from the Aschaffenburg University of Applied Sciences and the Czech Technical University in Prague proposed the project JEUMICO (an

acronym for Joint European Mirror Competence) to develop mirrors for X-ray telescopes. The aim of the project was the effective combination of experience, expertise and instrumentation of the Bavarian and the Czech partners in design, development, manufacturing, simulation and testing of innovative X-ray mirrors by the application of thin films. Especially astrophysical applications are considered in the proposed joint project. Within this project emphasis is given to the development of innovative thin and very lightweight X-ray mirrors for satellites with mirror thickness below 1 mm, which are formed into precise geometric shape and coated by thin iridium layers. Within this field the partners have complementary experience. The projects aim is to enhance the scientific cooperation between both research groups with the expected outcome of joint scientific publications and the organization of workshops and bilateral seminars on X-ray science. Intended long-lasting effects of the project are a regular exchange of scientists and students based on a living cooperation between both universities on an organizational level [2]. Finally the JEUMICO project was selected for funding for the years 2016 to 2017 and the project started with a kick-off meeting in Prague in February 2016. The logo of the JEUMICO-project is depicting the binational collaboration on mirror development (see figure 1).



Figure 1. The logo of the JEUMICO-project.

2. Project structure

The work breakdown structure of the JEUMICO-project is shown in figure 2. The work is split into two sub-projects, the first targeting the technical part of X-ray mirror development and the second part is dealing with the cooperation between the partner institutes, with scientific publications and with the transfer of the project results to industry. Eight individual work packages have been defined. Please note that the granted funding is mainly dedicated to develop the bilateral scientific cooperation, and not for purchasing hardware equipment.

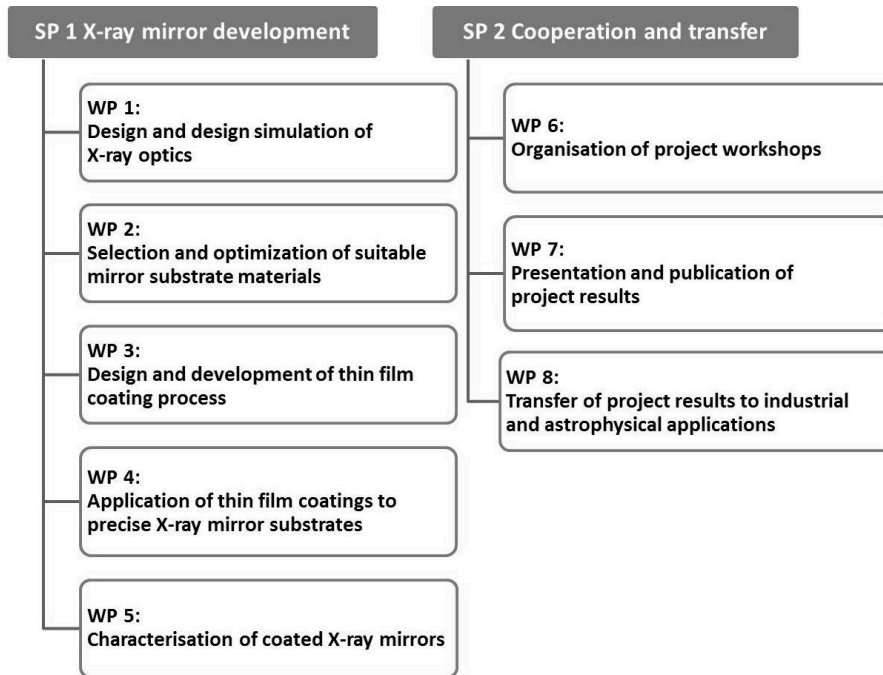


Figure 2. The work breakdown structure of the JEUMICO project.

3. Cooperation and staff exchange

One main aim of the joint funding program is to enhance the binational cross-border cooperation between Bavaria and the Czech Republic by an exchange of scientific staff between the involved partner organizations. In this context research stays of two young Czech Ph.D. students at Aschaffenburg University have been already organized in the framework of the JEUMICO project. One Czech Ph.D. student completed a six-week research stay at Aschaffenburg University in autumn 2016, as shown in figure 3. The scientific results presented within this paper are mainly based on the corresponding project work.

During spring 2017 a second Ph.D. student from Prague joined the German research group for three week, working on a more theoretical astronomical topic. More such research visits of Ph.D. students are in preparation, demonstrating a living partnership between the Czech Technical University in Prague and the Aschaffenburg University of Applied Sciences.



Figure 3. Research visit of a Czech PhD student at Aschaffenburg University during September/October 2016.

4. Coating development campaign

Based on a bionic approach we had chosen a special Lobster eye optics design in Schmidts arrangement, which uses dual reflections to increase the collecting area of astronomical X-ray telescopes (Hudec et al., 2015a), (Hudec et al., 2015b). The individual mirrors of this wide-field telescope are made of flat silicon wafers coated with reflecting iridium (Ir) coatings, as this material is promising high reflectivity in the X-ray range of interest. The new optics is designed as a hybrid between two types of reflective optics, of Kirkpatrick-Baez design, which uses parabolically curved mirrors, and of Lobster Eye design in Schmidts arrangement, using two sets of flat mirrors (Urban et al., 2016). Thereby this hybrid approach consists of two separated mirrors sets, turned for 90 degrees, as LE in Schmidts arrangement. For the complete set of telescope mirrors 4×16 individual mirrors are needed (Döhning et al., 2016). Radio frequency (rf) magnetron sputtering technology is available at Aschaffenburg University of Applied Sciences for the mirror for coating processes, using sputtering equipment type VPA 21 supplied by Aurion Anlagentechnik GmbH (Germany). Superpolished silicon wafers have been chosen as substrates for the X-ray mirrors of the lobster-eye telescope. These wafers from semiconductor industry are manufactured with high polishing precision and with a low surface micro-roughness. The substrates have a thickness of 0.70 mm, for the intended application they are cut to di-

mensions of 70 mm x 150 mm. During the joint coating development campaign also delamination of coated iridium layers has been observed. These effects are violating the requirement of long-term stability of the mirrors respectively their coatings. By applying an intermediate chromium adhesion layer a suitable mirror coating was achieved, resulting in a first mirror prototype [3] [4]. The mirror prototype is depicted in figure 4. The Ir/Cr-coated X-ray mirrors have been jointly developed within the JEUMICO project during the six-week research stay of the first Czech PhD student.



Figure 4. Prototype of an Ir/Cr-coated X-ray mirror.

5. Organisation of meetings and Workshops

According to the intention of the joint call to enhance the cooperation between scientists from Bavaria and the Czech Republic, several project meetings have been organized either in Prague or in Aschaffenburg. An impression of the JEUMICO kick-off meeting is given in figure 5. In addition, several scientific workshops have been organized by the Czech group, which are co-financed by the granted JEUMICO project funding as foreseen in the initial project proposal. The INTEGRAL/BART workshops (IBWS) are a successful series of workshops



Figure 5. JEUMICO-team at the projects kick-off meeting in February 2016.

dedicated to high energy astrophysics and supporting ground-based experiments (<http://www.ibws.cz>). These workshops are organized by the Czech Technical University in Prague and usually held in Karlovy Vary (Carlsbad, Czech Republic) during April or May every year. The 13th INTEGRAL/BART workshop was happening from 18th to 21st April 2016 and the 14th workshop was held from 3rd to 7th April 2017. Both workshops have been co-sponsored by the JEUMICO project to allow social events. Joint scientific contributions from the Bavarian and the Czech partners have been part of these two international conferences and corresponding JEUMICO project meetings have been organized. The International Workshop on Astronomical X-Ray Optics (AXRO) is an inter-

national conference series organized in Prague by the Czech partners [8]. Usually some review talks are given from leading international scientists in this field plus some presentations of relevant Czech scientists. The goal of the workshop is to present and to discuss recent and future technologies for X-ray astronomy missions. These missions require a development of mostly innovative technologies, and it is intended to discuss the possibilities, the results obtained so far, and new ideas in detail. It is obvious that the requirements of future large space X-ray astronomy missions are so demanding that they need a truly interdisciplinary approach in a wide international collaboration. These technologies include X-ray optics based on Si wafers, advanced glass forming for precise X-ray optics, but also other possible technologies and alternatives, as well as related advanced metrology, measurements and tests. The AXRO conference in December 2016 has been also co-sponsored by the JEUMICO project budget (<http://axro.cz>). Also here scientific contributions from the JEUMICO project team have been presented.

6. Publications and public relation measures

One strong personal motivation especially for young scientist like Ph.D. students and Post-Doc researchers to work in scientific projects is the opportunity to publish their results and to extend their own list of publications with respect to their individual future scientific career. Therefore the scientific output of the JEUMICO project was already published in several joint publications. Furthermore the involved scientists presented their work in oral contributions at conferences or in scientific posters. Nowadays marketing and promotion become more and more important also for scientific projects. Target groups are on the one hand the public in general and on the other hand the funding organizations. Both, in Germany and in the Czech Republic, universities need to attract more students especially for their STEM degree programs, in sciences, technology, engineering, and mathematics. Furthermore the scientific community has to demonstrate to the public, that the provided funding at least tax money - is a meaningful investment. Indirectly such public relation measures by the projects are also influencing decisions of the funding agencies: projects well aware in the public will probably get funding more easily. Also within the JEUMICO project PR-measures have been initiated. A few press releases on the project have been posted at the homepage of Aschaffenburg University, and two articles have been placed in a local German newspaper. In connection with the AXRO workshops also several articles about this event have been published in Czech newspapers. Even broadcast contributions about this event have been on air at local radio stations in Prague.

7. Summary and outlook

The development of mirrors for wide-field X-ray telescopes of modified lobster eye design is presented. The corresponding mirror segments are based on substrates of polished flat silicon wafers. The mirror substrates are coated with thin iridium films, as this material is promising high reflectivity in the X-ray range of interest. Thereby the coating process parameters are optimized in the context of the expected reflectivity of the X-ray mirrors. An intermediate layer of chromium helped to overcome the problem of stress-induced cracks within the iridium layer or even its delamination. In near future measurements of assembled mirror modules optical performances are planned at an X-ray test facility. For 2018 it is planned to launch the qualified telescope in a recently proposed NASA rocket experiment. The presented work was done in a bilateral collaboration between the Aschaffenburg University of Applied Sciences and the Czech Technical University in Prague. The political intention to enhance the scientific cooperation between two neighboring countries in Europe and the corresponding generous binational funding by a joint call allowed this project to be procured. Just recently, in April 2017, funding for the follow-up project TRILAMICO (an acronym for: Trilateral Mirror Collaboration) was granted by the Bavarian-Czech University Agency BTHA. So the successfully started joint work will continue.

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