

THE DEDICATED ACCELERATOR R&D FACILITY "SINBAD" AT DESY

Ulrich Dorda, Ralph Wolfgang Assmann, Kostyantyn Galaydych, Willi Kuroepka, Barbara Marchetti, Daniel Marx, Frank Mayet, Grygorii Vashchenko, Thomas Vinatier, Paul Andreas Walker, Jun Zhu, DESY, Hamburg, Germany
Arya Fallahi, Franz Xaver Kaertner, Nicholas Hill Matlis, CFEL, Hamburg, Germany

Abstract

We present an overview of the dedicated R&D facility SINBAD which is currently under construction at DESY. The facility will host multiple independent experiments on the acceleration of ultra-short electron bunches and advanced acceleration schemes. In its initial phase, SINBAD will host two experiments: AXSIS and ARES. The AXSIS collaboration aims to accelerate fs-electron bunches to 15 MeV in a THz driven dielectric structure and subsequently create X-rays by inverse Compton scattering. The first stage of the ARES experiment is to set up a 100 MeV S-band electron linac to produce ultra-short electron bunches with excellent beam arrival time stability. Once this is achieved, the electrons will be ideally suited to be injected into experiments for testing advanced accelerator concepts e.g. DLA experiments in the context of the ACHIP collaboration. In the long term, external injection into a laser driven plasma acceleration stage is targeted as well.

INTRODUCTION

SINBAD is a dedicated accelerator R&D facility currently under construction at DESY, Hamburg. Located in the former DORIS-facilities it is at the heart of DESY and provides sufficient space to host multiple independent accelerator experiments and the associated infrastructure (see Fig. 1). The former DORIS accelerator has been dismantled and the building refurbished so that it is now ready for the installation of the new accelerators with the associated infrastructure (see Fig 2). A dedicated hall is available to provide the basic infrastructure (water, electricity) to all experiments. In the first stage SINBAD will host two experiments, which are detailed in the following sections. In the future, the remaining free space may be used for further experiments like plasma acceleration in the context of EUPRAXIA [1].

ARES-LINAC

The ARES linac (Accelerator Research Experiment at Sinbad) is a normal conducting 100 MeV S-band linear accelerator for the production of low charge beams (0.5-30 pC) with (sub-) fs duration and excellent arrival time stability. The procurement of the individual components is currently ongoing [2] with the start of the beamline installation planned for winter 2017. The infrastructure installation has started with the clean room for the photo cathode laser being prepared, the basic electricity in the tunnel refurbished, the crane renovated and the water infrastructure rebuilt from scratch including a new connection to the global DESY-cold water circuit. Special attention is also being put on a good



Figure 1: Overview of the SINBAD R&D facility. Only half of the available tunnel area will be used for the two initial experiments.



Figure 2: Photos of the current status of the SINBAD accelerator tunnel. The old Doris accelerator and its infrastructure is removed, the building structure refurbished and the installation of the new infrastructure has started.

grounding network and the precision water cooling system for the RF-structures to achieve the ambitious stability goals (~ 10 fs). For this purpose a dedicated test-stand is currently being set up and the final location in the tunnel is close to the structures to minimize delay times of the control loops. The overall layout of the facility is optimized within the constraints of the preexisting building to e.g. minimize the path lengths of the LLRF-cables and waveguides to allow for a fast feedback. The rack-room is located in the cellar with the LLRF-racks defining the layout to have the shortest possible path to the RF-structures.

In the first stage a slightly modified version of the REGAE S-band RF-gun [3] followed by a ~ 2.5 m beam-line for

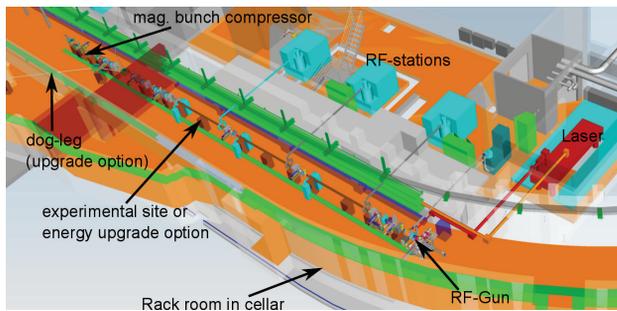


Figure 3: Sketch of the ARES linac in the accelerator tunnel with the associated infrastructure, which is located to minimize distances to allow fast feedback systems.

beam diagnostics including a spectrometer dipole will be installed. In parallel, a study of adding an additional solenoid even closer to the gun (between gun and RF-incoupler) is being carried out in order to improve the transverse emittance of the linac. In this case a bucking coil would also be needed to have zero magnetic field at the cathode. The gun will be powered by a 6 MW klystron from Toshiba with a Scandinova K1 modulator. A pulse length of $6\mu\text{s}$ was chosen to allow the LLRF to regulate on the RF before the beam is generated. In mid 2018, two $\sim 4.5\text{m}$ long S-band RF linac structures - surrounded by solenoids and powered by individual RF-stations - will be added. While these structures could accelerate the beam to 160 MeV if operated on crest, we aim only for ~ 100 MeV, using the remaining RF to either compress the beam via RF-compression or compress in a magnetic bunch compressor after imposing an energy chirp [4, 5]. Finally, an upgrade option with a dogleg to a second experimental site is being considered [6].

A collaboration with CERN and PSI was started to develop a X-band TDS-system with variable polarization [7]. In combination with a suitable beam line design [8] this would allow the characterization of longitudinal properties of bunches with duration ranging from few fs up to sub-fs. The novel variable polarization feature offers also opportunities for new applications such as the reconstruction of the 3D charge distribution [9].

ARES EXPERIMENTS

Once the ARES linac is operational it will be used to study the limits of various bunch compression methods as well as to externally inject the beam into so called advanced acceleration schemes, to test beam diagnostics etc. Conveniently, there several laser labs are located adjacent to the ARES-linac area (see Fig. 3).

ACHIP

The concept of dielectric laser accelerators (DLA) [10] has gained increasing attention in accelerator research, because of the high achievable acceleration gradients (GeV/m). This is due to the high damage threshold of dielectrics at optical frequencies. In the context of the 'Accelerator on a Chip International Program' (ACHIP) we plan to inject

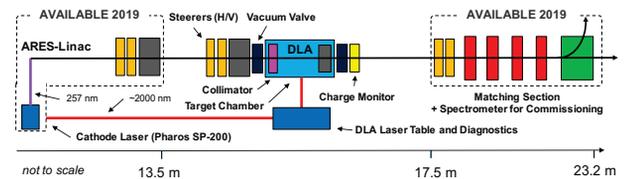


Figure 4: Preliminary experimental layout of the planned DLA-experimental site at the ARES-linac.

electron bunches into such structures. The SINBAD-ARES linac with its ultrashort bunches and targeted beam arrival time stability will be ideally suited for this purpose. For initial tests, a part of the power of the photocathode laser will be diverted, converted to $2\mu\text{m}$ and transported to the DLA experimental site at the end of the linac. A linac working point has been found [11] that allows the use of the solenoids surrounding the linac RF-structures to focus the beam to the entrance of the DLA structures (Fig. 4). As an upgrade option and in order to obtain inherent synchronization and even shorter bunches, a concept to micro-bunch the beam synchronized to the DLA laser is being studied [12]. In the first stage, the experiment will be set-up at the location that is reserved for an additional linac structure as an energy upgrade option. The respective preliminary layout is shown in Fig. 4.

THz Experiments

While the intention of AXISIS is to set up a fully optical accelerator and X-ray source, the testing of individual components e.g. the linac, inverse Compton Scattering (ICS) with help of a well characterized beam is of interest. Conveniently a suitable laser lab hosting the THz-laser is just behind the tunnel wall. The solenoids around the linac structures can be used to focus the beam into the THz-structures without loss and with a suitable bunch length to fit into the THz-buckets. In addition to these acceleration experiments, this option would allow to measure the bunch length with the 3-phase method and THz dielectric-loaded waveguides [13]. Finally THz would be an interesting candidate for a transverse deflecting structure complementing the planned X-band TDS.

Trans-National Access via ARIES TNA

ARIES [14] is an integrating activity project which aims to develop European particle accelerator infrastructures, co-funded under the European Commission's Horizon 2020 Research and Innovation program. In this context access to the SINBAD-ARES linac is provided to external transnational users for several weeks each year free of charge. Starting from spring 2019 users will be financially supported to come to SINBAD and use the electron beam e.g. testing beam diagnostics, test acceleration methods etc.

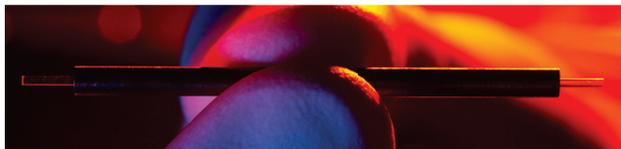


Figure 5: A dielectric loaded waveguide like what will be used at AXSIS.

Upgrade Plan to Laser Plasma Acceleration with External Injection

Subject to the availability of funding, it is planned to move a high power laser from another site at DESY into the central SINBAD hall. The laser would then be used to drive a plasma wake into which the ARES beam would be injected and further accelerated to about 1 GeV. The required matching section has been studied [15] and detailed studies on the plasma started [16].

AXSIS

The AXSIS (Attosecond X-ray Science: Imaging and Spectroscopy) project is a ERC-synergy grant funded project of the groups of R. Assmann, H. Chapman, P. Fromme and F. X. Kärtner aiming to develop a compact ~ 15 MeV accelerator based on THz-acceleration in dielectric loaded waveguides (see Fig. 5). The ultrashort electron bunches are then focused and used to create X-rays via Inverse Compton scattering (ICS). The dedicated parts in the SINBAD areal have been prepared to host the accelerator setup and the installation of the required associated facilities (laser clean room, control room, infrastructure, bio-labs) is starting up. In the last years efficient methods for laser-based THz-production have been developed [17–21]. In parallel a first version of a THz-driven gun was developed [22] and produced. Electrons with few keV energy were observed and characterized [23]. Based on the results, the final AXSIS gun will now be developed. The initial version of the gun aims to deliver electrons at around 150 keV. As the electrons at this energy are not yet relativistic, a tapered linac design (where the phase velocity is adapted to change along with the acceleration) or a two stage linac is being considered. Finally, multiple options of focusing the beam from the linac exit to the ICS-point have been studied [24].

CONCLUSION

We have presented the status and plans of the dedicated accelerator R&D facility SINBAD at DESY. The renovation of the building infrastructure is completed and the infrastructure for both initial experiments is being installed. The procurement for the 100 MeV ARES linac is ongoing with the installation starting in fall 2017. The AXSIS project has experimentally tested first THz gun designs, made progress in the efficient THz generation and continued in the development of the overall THz accelerator design.

ACKNOWLEDGEMENT

The authors would like to thank the colleagues from DESY technical groups for their continuous support to the realization of the project. The AXSIS related research has received funding from the European Research Council under the European Union's Seventh Framework Programme (FP/2007-2013) ERC Grant Agreement N. 609920. The ACHIP related research is funded by the Gordon and Betty Moore Foundation as part of the Accelerator on a Chip International Program.

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