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THE EXPERIMENTAL AREA AT THE ARES LINAC

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Abstract

The ARES (Accelerator Research Experiment at SINBAD) linac at the accelerator R&D facility SINBAD (Short innovative bunches and accelerators at DESY) will drive multiple independent experiments including the acceleration of ultrashort electron bunches. In addition the linac will host an experimental area, open for transnational access, to study advanced high gradient, laser driven, acceleration concepts, like the ones studied within the ACHIP (accelerator on a chip) collaboration. The area will be operational autumn-2019. This paper will report on the current status of the experimental area, including hardware parameters, beam optics, achievable beam parameters, design of the experimental chamber and commissioning plans. The modification plans for a micro-bunching experiment in the frame of the ACHIP experiment and future upgrade plans will be shown and discussed in detail.

INTRODUCTION

ARES Linac

SINBAD is a dedicated accelerator R&D facility in the former DORIS tunnel at DESY Hamburg [1]. The goal is to test advanced acceleration techniques, such as Laser driven plasma Wake-Field Acceleration (LWFA), Dielectric Laser Acceleration (DLA) and THz driven acceleration, in independent experiments. ARES at SINBAD is a linear accelerator with a target energy of 50-160 MeV which is currently in the construction and commissioning phase [2,3]. The facility will provide a low charge, remarkably short electron probe beam with excellent arrival-time stability. The design parameters of the electron beam are summarised in Tab. 1.

ARES consists of a normal conducting 2.998 GHz RF photoinjector sending the electron bunches to two S-band RF cavities surrounded by four solenoids each. The travelling wave structures (TWS) are powered by two independent RF-stations. The ARES linac can accelerate the electron beam to a maximum beam energy of 155 MeV in the on-crest mode. A reduced final energy of 100 MeV is assumed since the linac not only accelerates the beam but also serves to chirp the bunch for bunch compression via velocity bunching and using a magnetic chicane [4]. For dedicated experiments the electron energy can be adjusted to 50 MeV. The gun is currently under conditioning and the installation of both linac cavities together with the solenoids is finished.

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Table 1: Target Electron Beam Parameters

	Unit	Value
Beam energy	MeV	50 - 160
Bunch Charge	pC	0.5 - 30
Number of bunches	-	1
Repetition Rate	Hz	1 - 50
Norm. emittance (rms)	µrad	0.1 - 1
Bunch length (rms)	fs	0.2 - 10
Arrival time jitter	fs	below 10

EXPERIMENTAL AREAS

Downstream of the TWS a longitudinal space of 4.2 m is reserved for the first experimental area (EA). It consists of an electromagnetic triplet structure, magnetic beam steerers, beam instrumentation and an experimental chamber. The EA is followed by the ARES matching section and the spectrometer setup [4]. In line with the upgrade plans for the ARES linac within the ATHENAe project the experimental area will move at a later stage to the ARES dogleg, freeing the space for an energy upgrade of the linac. A sketch of the ARES linac and the two positions of the experimental area is shown in Fig. 2. The available space upstream of the matching area for the first EA is shown in Fig. 1.

Figure 1: Picture of the space reserved for the first experimental area in the ARES tunnel.

A schematic layout of the experimental area is shown in Fig. 3. Electrons exiting the second travelling wave structure enter the EA from the right side, triplet magnets and correctors allow beam trajectory changes on the micrometer scale. Beam size and position can be measured with a standard ARES screen station [4]. Experiments have to be installed in an UHV vacuum chamber, a laser beam line and breadboards

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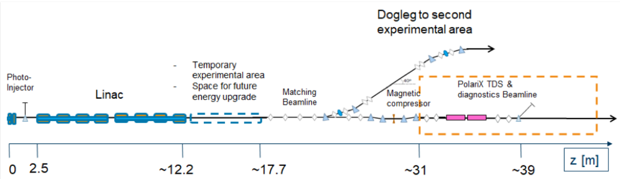

Figure 2: Sketch of the ARES Linac, the first experimental area will be located downstream of the 2nd TWS. In a later stage the experimental area will move to the dogleg.

allow also a laser in-coupling. First users of the ARES EA will be the ACHIP (accelerator on a chip) collaboration. The beam time can be requested via the ARIES transnational access programme [5]. The beam optics for the experimental area downstream of the TWS until the spectrometer screen is shown in Fig. 4.

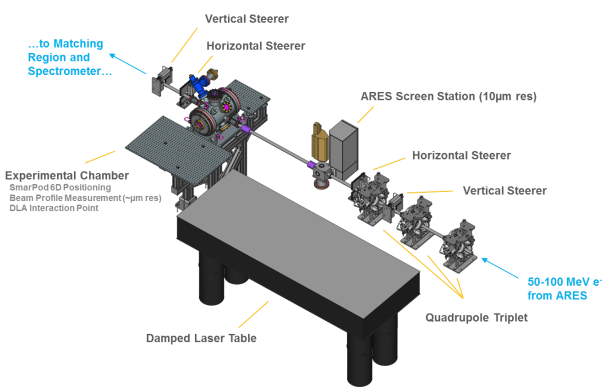

Figure 3: CAD model of the experimental area at the ARES linac. The three triplet magnets are located at the right, followed by a beam screen station and the experimental chamber.

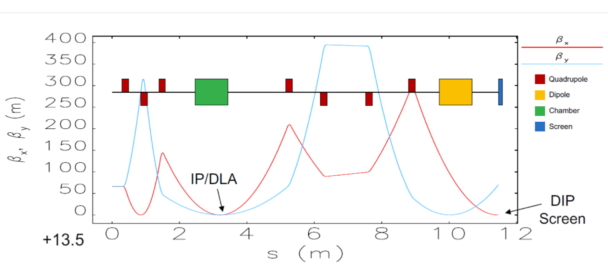

Figure 4: Beam optics for the experimental area, including triplet, experimental chamber, matching region and spectrometer setup.

Experimental Chamber

The experimental area will be equipped with a round UHV compatible experimental chamber with 25 cm diameter and a height of 35 cm. A cut through the final CAD model of the chamber is shown in Fig. 5. The chamber support will also hold two breadboards on both sides to allow the installation of laser beam optics. The chamber is damped from the support structure. The inner parts are accessible via removable flanges on both sides. The cut through the chamber illustrates the use of the different ports. 2 ports are use to transport the electron beam through the chamber, 2 ports are used for vacuum pumps, a camera including lenses will be installed on the top port, one view port and 2 cable feedthroughs are foreseen. The laser in-coupling windows are perpendicular to the electron beam trajectory. The chamber is currently in production and will be ready for installation in June 2019.

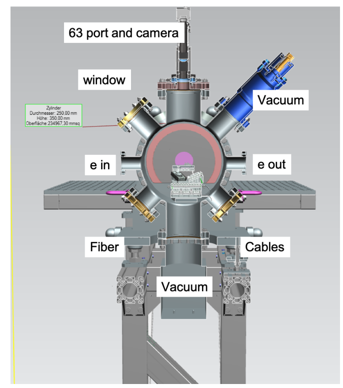

Figure 5: Vertical cut on electron beam axis through the experimental chamber. It shows the design and use of the different ports.

Hexapod Specifications

A SMARACT hexapod will be installed inside the chamber. The hexapod can transport 1 kg with 1 nm (1 µrad) precision. The movement range is 10 / 6 cm in the horizontal plane and 1 cm in vertical direction. The platform can be tilted up to 2 degrees. The hexapod is UHV compatible up to 1E-9 mbar. It is ready for installation in the chamber.

ACHIP EXPERIMENT

The first users of the experimental area will be the ACHIP collaboration, in a basic experiment the nominal ARES electron bunch will be directly coupled into the DLA structure. In a later stage also microbunching hardware will be installed.

ACHIP Experiment with Micro-Bunched Electron Beams

The main goal of the ACHIP-related experiment at ARES is to show net energy gain of externally injected electron bunches in grating-type DLAs [6]. An important other aspect is to also achieve this with shot-to-shot stability. In order to tackle this problem, at ARES an incoming relatively long (~ 150 fs) electron bunch is modulated inside an undulator, into which a laser pulse is colinearly injected

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in a way that it overlaps with the electron bunch in time and space. The external laser field consequently imprints an energy modulation $\Delta\gamma$, which can then be transformed into a density modulation using a magnetic chicane that provides suitable longitudinal dispersion (R_{56}). If both this laser modulator and the DLA are driven by the same laser and the relative phase jitter between the two arms is negligible, intrinsic phase synchronisation between the ultra-short microbunches (~ 350 as) and the $\lambda_{\text{period}} = 2\,\mu\text{m}$ DLA field can be achieved [7, 8]

Laser Modulator

For this experiment a short hybrid-type undulator based on the PETRA U23 magnet and pole design was developed. In order to be able to couple in the modulating laser colinearly with the main axis of the accelerator, the ACHIP experiment is planned to be placed in a closed horizontal orbit bump of $\Delta x \approx 5.2$ mm. The undulator acts as the second steerer and hence has to accept an incoming trajectory angle of 0.5°, which is achieved by removing the first pole. In order to simplify the design, the gap size was chosen to be fixed. Table 2 summarises the parameters of the undulator, obtained from RADIA [9, 10] simulations. This device is currently in production.

Table 2: Parameters of the Undulator

Parameter	**Value**
Magnets	13 (VACODYM 775 TP)
Poles	13 (VACOFLUX 50)
Full oscillation periods	5
Fixed gap size	10.7 mm
Device Length	15.6 cm
Entrance angle	0.5°
$\langle B_0 \rangle$	0.61 T
Undulator parameter	1.27
E_{res} @ 2050 nm	52.42 MeV

Bunching Chicane

The magnetic chicane must provide enough longitudinal dispersion R_{56} to maximise the bunching factor $b(\Delta\gamma, R_{56})$ for a given energy modulation $\Delta\gamma$ from the modulator. For this the final prototype of the permanent magnetic XFEL-type phase shifter (see [11]) will be used.

The device is comprised of two hybrid-like magnet/pole arrangements, which together generate a double sine field pattern. The phase shifter acts similar to a four dipole chicane. Tuning of the peak magnetic field is possible by adjusting the gap, which can be done remotely. Based on measurements shown in [11] the range of achievable values of R_{56} can be calculated [12]. For the ACHIP stage 2 working point the central energy of the electron bunch is 52.42 MeV. This yields

$$R_{56,\text{min}} = 0.0095\,\text{mm},\; R_{56,\text{max}} = 0.778\,\text{mm}$$

corresponding to a gap of 100 mm and 10 mm respectively. Table 3 summarizes the technical specifications of the XFEL phase shifter.

Table 3: Technical Specifications of the XFEL Phase Shifter (Data Taken From [11])

Parameter	**Value**
Min. gap	10 mm
Max. gap	>100 mm
Gap control accuracy	±0.05 mm
Magnet material	NdFeB
Yoke material	ARMCO
Pole material	FeCo
Period length, λ_p	55 mm

Laser Specifications for the ACHIP Experiment

The specifications for the Laser System which will be used in the frame of the ACHIP experiment are summarised in Tab. 4:

Table 4: Technical Specifications of the DLA Laser System at ARES

Parameter	**Value**
Type	Ho:YLF
λ	2050 nm
$\Delta\lambda/\lambda$	0.24 %
E_{pulse} (max)	2.2 mJ
E_{pulse} (compressed,max)	1.9 mJ
E_{pulse} (Kagome,max)	0.7 mJ
f_{rep}	1 and 5 kHz
t_{pulse}	3 ps
t_{pulse} (transform limited)	1.25 ps
t_{pulse} (Kagome)	0.4 ps

TIME LINE AND CONCLUSION

The design of the first experimental area at the ARES Linac is finished, the production of the chamber is almost finished, the magnets and the Hexapod are delivered. The design of the vacuum system and the support structures is ongoing. The installation of the experimental area and commissioning is foreseen in autumn 2019.

ACKNOWLEDGEMENTS

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