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STATUS OF THE FLUTE RF SYSTEM UPGRADE

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Abstract

FLUTE (Ferninfrarot Linac- Und Test-Experiment) is a compact versatile linac-based accelerator test facility at Karlsruhe Institute of Technology (KIT). Its main goal is to serve as a platform for a variety of accelerator studies and to generate intense ultra-short THz pulses for photon science. It will also serve as an injector for a Very Large Acceptance compact Storage Ring (VLA-cSR), which will be realized at KIT in the framework of the compact STorage Ring for Accelerator Research and Technology (cSTART) project. To achieve acceleration of electrons in the RF photo-injector and linac (from FLUTE) with high stability, it is necessary to provide stable RF power. For this goal, an upgrade of the existing RF system design has been proposed and is currently being implemented. This contribution will report on the updated RF system design and the commissioning status of the new RF system components.

INTRODUCTION

FLUTE [1] is an accelerator R&D facility that will allow the study of bunch compression with all related effects like space charge, coherent synchrotron radiation (CSR) as well as the systematic investigation of different generation mechanisms for coherent THz radiation in a comparison between experiment and theory. It will be used as a test bench for the development of new diagnostics and instrumentation for fs bunches. Furthermore, it will serve as an injector for the compact storage ring of the cSTART project [2], and to enable study for future compact, broadband accelerator-based THz user-facilities. All applications mentioned above will require, and strongly benefit from, a high stability of electron beam parameters (from 40 up to 90 MeV), low dark current, and a repetition frequency up to 50 Hz. In order to achieve these parameters, an upgrade of the FLUTE RF system has been proposed. In this contribution, an update on the new RF system will be presented. The main components of the new FLUTE RF system include: new RF photo-injector, two RF units (one for the new RF photo-injector and the other one for the linac). Also, two new RF waveguide systems for the RF photo-injector and the linac have been designed.

UPGRADE OF THE RF SYSTEM

In [1] the existing FLUTE layout is described. It consists of a 45 MW klystron where RF power is split between the RF photo-injector and the linac. The RF photo-injector gun used at FLUTE was designed and operated at CTF2, CERN [3]. It consists of 2.5 cells and was optimized for high charge beams (bunch trains with up to 13 nC per bunch). The energy of electrons that can be achieved with the existing FLUTE configuration at the end of the linac is up to 50 MeV. To increase the stability of the electron beam parameters and also increase the electron energy at the output of the linac, two new RF units will be utilized. Each RF unit consists of a modulator and a klystron. The first RF unit will provide RF power for the new RF photo-injector and the second for the linac. The first RF unit (K100) was already delivered by ScandiNova [4] and tested at FLUTE. The results of the site acceptance tests (SAT) for K100 RF unit are shown in Table 1. The RF unit (K300) that will provide RF power for the linac is presently being assembled by ScandiNova and will be delivered in the middle of 2022. The main design parameters of the K300 RF unit are presented in Table 2.

Table 1: K100 RF Unit SAT Results

Parameter	Value	Unit
RF power	10.6	MW
Frequency	3	GHz
Output voltage	177	kV
Output current	135	A
RF pulse top flatness	1	%
RF pulse length (top)	4.5	usec
Repetition rate	50	Hz
Pulse to pulse voltage stability	18	ppm

Table 2: K300 RF Unit Design Parameters

Parameter	Value	Unit
RF power	36.8	MW
Frequency	3	GHz
Output voltage	285	kV
Output current	315	A
RF pulse top flatness	1	%
RF pulse length (top)	4.5	usec
Repetition rate	50	Hz
Pulse to pulse voltage stability	20	ppm

New RF Photo-Injector

The new RF photo-injector has been designed and built by RadiaBeam [5]. It has 1.5 cells, electron energy up to 5.5 MeV (with 9.5 MW of RF power), exchangeable cathode and repetition rate of up to 50 Hz. It can operate in a wide range of bunch charges from 1 pC to 1 nC with a copper cathode. It has been successfully tested with low RF power during factory acceptance tests (FAT) and the results of the FAT as well as the main design parameters are presented in Table 3. High power RF tests at FLUTE are planned after delivery in the middle of 2022.

The RF photo-injector will be delivered with a new solenoid and an alignment stand for the RF photo-injector. The solenoid itself will be aligned on the existing motor-

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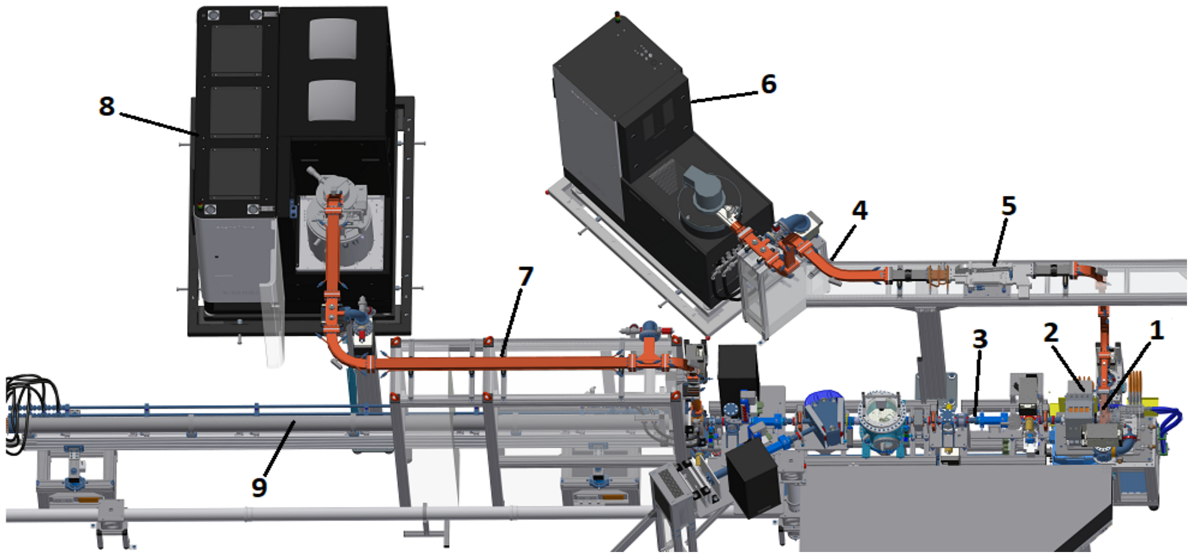

Figure 1: Main components of the new RF system of FLUTE. 1 – RF photo-injector, 2 – solenoid, 3 – diagnostic sections, 4 – K100 waveguide system, 5 – circulator, 6 – K100 RF unit, 7 – K300 waveguide system, 8 – K300 RF unit, 9 – linac.

ized table, which will be upgraded with another movable stage to 5 movable axes.

Table 3: New RF Photo-Injector' Parameters

Parameter	Value	Unit
Input RF power	9.5	MW
Output energy	5.5	MeV
Operating frequency	2.997	MHz
Repetition rate	50	Hz
Bunch charge	1-1000	pC
Pulse length	4	usec
Peak cathode field	120	MV/m
External coupling factor	1.06	
Laser injection	On-axis	

General Configuration of the New RF System

The general configuration of the new FLUTE RF system is shown in Fig. 1. As one can observe the 10 MW K100 RF unit is connected to the new RF photo-injector via an RF waveguide system. This waveguide system includes a circulator which requires operation under SF_6 pressure. To minimize the volume of SF_6 gas, the circulator is closed directly from both sides by two RF windows, which allows operation of the rest of the waveguide system under vacuum. The waveguide system for the 37 MW K300 RF unit will be operated fully under vacuum.

Main advantages of the new RF system compared to the existing FLUTE RF system:

- Higher RF stability,
- Lower dark current,
- Higher output electron beam energy (up to 90 MeV),
- High repetition rate (up to 50 Hz),
- More precise positioning for the new RF photo-injector due to the separate alignment stand,
- More precise magnetic field of the solenoid,
- Smaller volume which requires SF_6 gas,
- Fully vacuum waveguide system for the linac.

SUMMARY

A new RF system for FLUTE has been designed and is in the process of implementation. The new RF system achieves higher stability of the electron beam and higher energies (up to 90 MeV) compared to the existing RF system. Furthermore, the new RF photo injector generates far less dark current, which provides great benefits especially for operation in a low bunch charge regime (~1 pC). The 37 MW of RF power that can be provided by K300 RF unit allows for future upgrade of FLUTE to provide even higher electron energy if an RF pulse compressor is used which significantly increases peak RF power and allows the use of a second linac.

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