Status and First Operation of Gyrotron Teststand FULGOR at KIT

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***Abstract*— FULGOR, the new KIT gyrotron teststand for megawatt-class gyrotrons, will be presented. Results of initial experiments using a 1.5 MW 140 GHz short pulse pre-prototype gyrotron will be discussed.**

I. INTRODUCTION

T Since the mid 80's of the last century KIT is consequently pursuing the goal to develop high power gyrotrons which are widely used as RF source for ECRH and ECCD in fusion devices. KIT is currently establishing a new teststand for gyrotron development. FULGOR (**FU**sion **L**ong Pulse **G**yrotron Lab**OR**atory) will allow to test gyrotrons with a performance which is well beyond the state-of-the-art. The major subsections of FULGOR are: HVDCPS (High Voltage Direct Current Power Supply), superconducting magnet, cooling system, control system, calorimetric and microwave diagnostics.

II. COMPONENTS OF FULGOR

The HVDCPS (High Voltage Direct Current Power Supply) was manufactured by Ampegon AG, CH, it takes advantage of the **E**nhanced **P**ulse **S**tep **M**odulator technology which allows intermediate tapping points for highly efficient operation of gyrotrons with multi-staged depressed collectors and very low noise levels. The power supply is designed for 10 MW CW operation at 90 kV and 120 A, for short pulse operation (< 5 ms) 130 kV at 120 A is possible. Specific modular units make sure that in case of an arc in the gyrotron the energy is limited to 10 J. The rise time of the pulse is < 50 μs, the modulation frequency is up to 5 kHz.

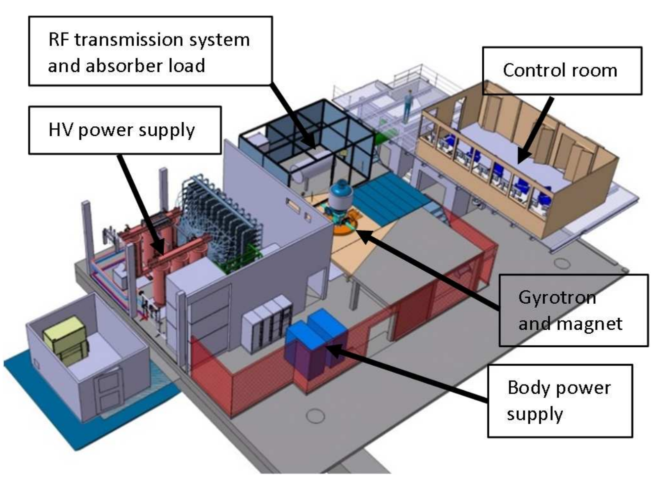

Fig. 1. CAD view of FULGOR teststand and its components.

An additional CW body power supply (BPS) for operation of conventional single-stage depressed collector gyrotrons has been installed. This power supply delivers an output voltage of up to 50 kV at 100 mA.

Future gyrotrons which will be developed for fusion applications will require higher operating frequencies compared to state-of-the-art. This will call superconducting magnets which allow for operation well above 200 GHz. The procurement of an adequate magnet is under progress.

The RF power of the gyrotron will be transmitted with a quasi-optical system (2 focusing mirrors, 2 polarizers) to the RF absorber load. The cylindrical 2 MW CW absorber load uses water cooled Teflon pipes for microwave absorption, the diameter is approximately 1 m, the length is 2 m. The system is operated under ambient air.

The FULGOR test facility will be equipped with a flexible and extensive diagnostic system which allows the full characterization of gyrotrons in short pulse and long pulse operation. A new frequency diagnostic system has been built in the range 170 – 260 GHz, it will include a filterbank system that offers a bandwidth of 18 GHz with 2 GHz sub-channels. This system gives quick overview of the oscillating frequency during the pulse. Additionally a pulse spectrum analysis system with a high resolution (< 100 kHz) offers the possibility to analyze the frequency variation during the pulse. Finally it is planned to install a Pulse Spectrum Analysis System (PSA) up to 260 GHz as an upgrade of the existing one.

The control system for the gyrotron and teststand components is based on an industrial standart, SIEMENS TIA with S1500 CPU. It controls the status of the gyrotron and the teststand and makes sure that limitations for the system are not exceeded. The visualisation gives a quick and comprehensive overview to the operator of the status of the system. Due to the strong limitations on the maximum energy that is allowed to be deposited in the gyrotron in case of an arc, a 16 channel fast interlock system has been developed. A typical reaction time of this system is 8.5 μs, it is used for fast signals, e.g. arc detectors and vacuum pumps to trip the power supply.

The cooling system of the facility is capable of handling a total power of 10 MW. Each secondary cooling channel which is directly connected to the gyrotron is equipped with individual temperature sensors and flow meters to allow calorimetric measurements. Very precise

Fig. 2. View of RF transmission system and absorber load

temperature sensors and flow meters are installed in the primary cooling circuits which directly cool gyrotron subcomponents to offer exact measurement of the power loading of the different cooling channels in the gyrotron. Online values of temperature, flow rate, pressure and conductivity of the water are visible to the operator and operation is electrically interlocked by threshold values.

III. First Experimental activities

First tests of the teststand FULGOR have been performed with a short pulse 1.5 MW, 140 GHz gyrotron. This tube has been extensively tested at an other teststand [1] and it is used as a reference to verify the proper operation of the new teststand. A new cryo-free superconducting 6 T magnet is used for these tests. Fig. 3 shows the installation of the gyrotron into the magnet. The gyrotron has been operated with parameters close to nominal ($U_{cathode}$ ~ 70 – 85 kV, I_{beam}~ 40 – 55 A) for ~ 1 ms. Without further optimization of the operating parameters the RF power achieved was 500 – 700 kW. Fig 4 (top) shows first measurements of voltage and electron beam, Fig 4 (bottom) shows first microwave produced at the teststand FULGOR.

IV. Conclusions

The **FU**sion **L**ong Pulse **G**yrotron Lab**OR**atory teststand FULGOR has been constructed during the past years. All major components have been installed and successfully tested (except sc magnet). First tests with a short pulse gyrotron have been performed in order to verify the poper operation of the complete system. In the next step a 1.5 MW 140 GHz long pulse prototype gyrotron will be installed and the performance will be investigated.

Acknowledgement

Part of this work has been carried out within the framework of the EUROfusion Consortium, funded by the European Union via the Euratom Research and Training Programme (Grant Agreement No 101052200 — EUROfusion). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the European Commission can be held responsible for them.

A big acknowledgement is dedicated to the members of the technical team: T. Kobarg, D. Kranz, R. Lang, W. Leonhardt, G. Marschall, D. Mellein, A. Papenfuß, J. Weggen, A. Zein.

References

[1]. Z. Ioannidis, et.al., "*Generation of 1.5MW-140GHz pulses with the modular pre-prototype gyrotron for W7-X*", *IEEE Electron Device Letters,* ***42****, 6, June 2021,* DOI: 10.1109/LED.2021.3073221

Fig. 3. Installation of a short pulse 1.5 MW 140 GHz gyrotron.

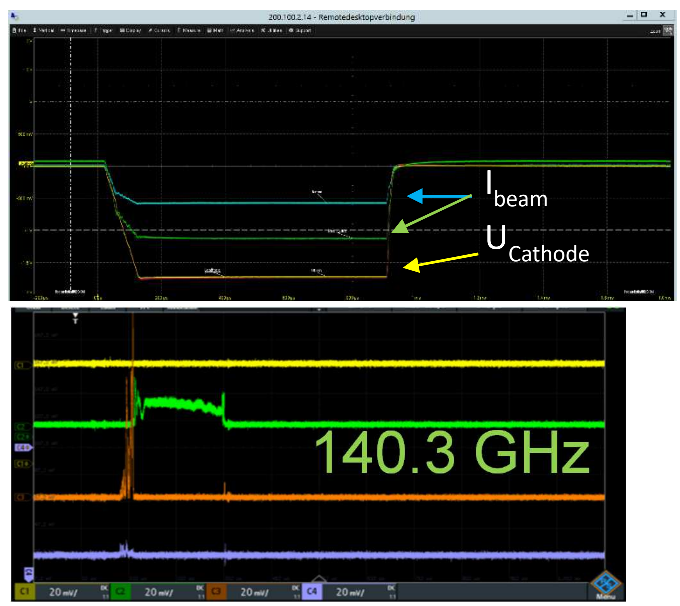

Fig.4: Measurement of beam current and cathode voltage for ~ 1 ms pulse (top), first RF detection (filterbank signal) on FULGOR teststand (bottom).