STATUS OF 30 GHZ FACILITY FOR EXPERIMENTAL INVESTIGATION OF THE COPPER CAVITY LIFETIME (CLIC COLLIDER PROJECT)*

A.V. Elzhov, E.V. Gorbachev, A.K. Kaminsky+, V.V. Kosukhin, E.A. Perelstein, N.V. Pilyar, T.V. Rukoyatkina, S.N. Sedykh, A.P. Sergeev, A.I. Sidorov, V.V. Tarasov
Joint Institute of Nuclear Research, Dubna, Russia
N.S. Ginzburg, S.V. Kuzikov, N.Yu. Peskov, M.I. Petelin, A.S. Sergeev, N.I. Zaitsev
RAS Institute of Applied Physics, Nizhny Novgorod, Russia

Abstract

The facility for experimental investigation of a copper cavity lifetime under multiple action of 30 GHz microwave power pulses is being created now by the collaboration of CLIC (CERN), JINR (Dubna) and IAP RAS (Nizhny Novgorod). A design of the test cavity, an estimation of the operating parameters of the FEM oscillator and the RF power transmission line was already discussed at FEL'03. Last year was devoted to the achievement of the design parameters of all of the elements of the facility. We have developed the equipment and the method of RF transmission line adjustment, improved the stability of the linac power supplies, created the new system of data acquisition. Effect of central mode splitting in Bragg resonators is one of the problems under study. Start of the full-scale experiments is planned to the end of 2004.

1 INTRODUCTION

One of the strict limits on the accelerating gradient in future linear colliders is the fatigue of the copper wall of high-gradient accelerating structure due to multiple action of powerful RF pulses [1]. Experimental investigation of this limitation at the frequency of 11.4 GHz has been carried out in SLAC for several recent years [2]. A similar research at the frequency of 30 GHz is prepared now by collaboration of CLIC team (CERN) [3], JINR (Dubna) and IAP RAS (Nizhny Novgorod) groups. The nearest our goal is a wall temperature rise about 200 K with the statistics of 10^6 pulses [4]. The source of RF power is JINR–IAP FEM oscillator with Bragg resonator which provides the 25 MW/150 ns pulses with spectrum width not greater than 30 MHz [5, 6] at the operating mode TE_{11}. The breakdown-safe mode TE_{01} has been chosen as the operating mode of the tunable copper test cavity which simulates the CLIC accelerating structure.

A key element of the experimental facility is the RF power transmission line. It should provide the high efficiency, elimination of the breakdown at the vacuum windows, possibility for diagnostics of the incident, reflected and transmitted RF power and radiation spectrum.

One of the effects under study is the mode splitting in FEM Bragg resonators observed both in cold and hot experiments. Possible reason of this undesirable effect is discussed.

2 RF TRANSMISSION LINE

The scheme of the RF transmission line is presented in Fig. 1. It contains FEM output horn with cylindrical insertion, long oversized waveguide with vacuum window inside it, a diagnostic film with detectors of incident and reflected power, two quasi-optic focusing mirrors, a movable reflector, long input waveguide with vacuum window, accepting horn with cylindrical insertion, TE_{11} to TE_{01} mode converter, a test cavity, an output horn with vacuum window and a detector of the transmitted power.

It is well known that a Gaussian wavebeam is the most suitable one for quasi-optic focusing mirrors. In our line the Gaussian beam is formed at the FEM oscillator output by the special horn with cylindrical insertion (Fig. 2) which provides the optimal phase shift between the initial TE_{11} mode (87% of power) and TM_{11} mode (13%) formed in the horn. The long output waveguide employs the phenomenon of wave-front self-reproduction in oversized waveguide (Talbot effect) [7]. The wavebeam in an oversized waveguide may be considered as a superposition of partial eigenmodes with different phase velocities. So the phase relations between the partial modes evolve spatially and become similar to the initial one at a certain length (e.g. ~ 90 cm for the FEM output waveguide we had used). While the Gaussian wavebeam is reproduced at the end of the waveguide, it is possible to find the cross-section with almost uniform amplitude of the RF field to install the vacuum window and eliminate the breakdown. It is also possible to reduce the influence of the reflected wave on the FEM oscillator. Efficiency of the Gaussian wavebeam reproduction is about 90% due to mismatching phases of high-order modes.

The thin film is installed between the FEM output waveguide and the first mirror at the angle of 45° with respect to the wavebeam. Small reflection from both sides of the film provides possibility of non-destructive control of both incident and reflected power pulses.

The distant-controlled movable reflector can be lifted from its conventional horizontal position to direct the

* This work is supported by grants №№ 04-02-17118, 03-02-16530, 02-02-17438 of Russian Foundation for Basic Research and by INTAS grant №03-51-5319.
+ Corresponding author: Dr. A.Kaminsky, E-mail: alikk@sunse.jinr.ru

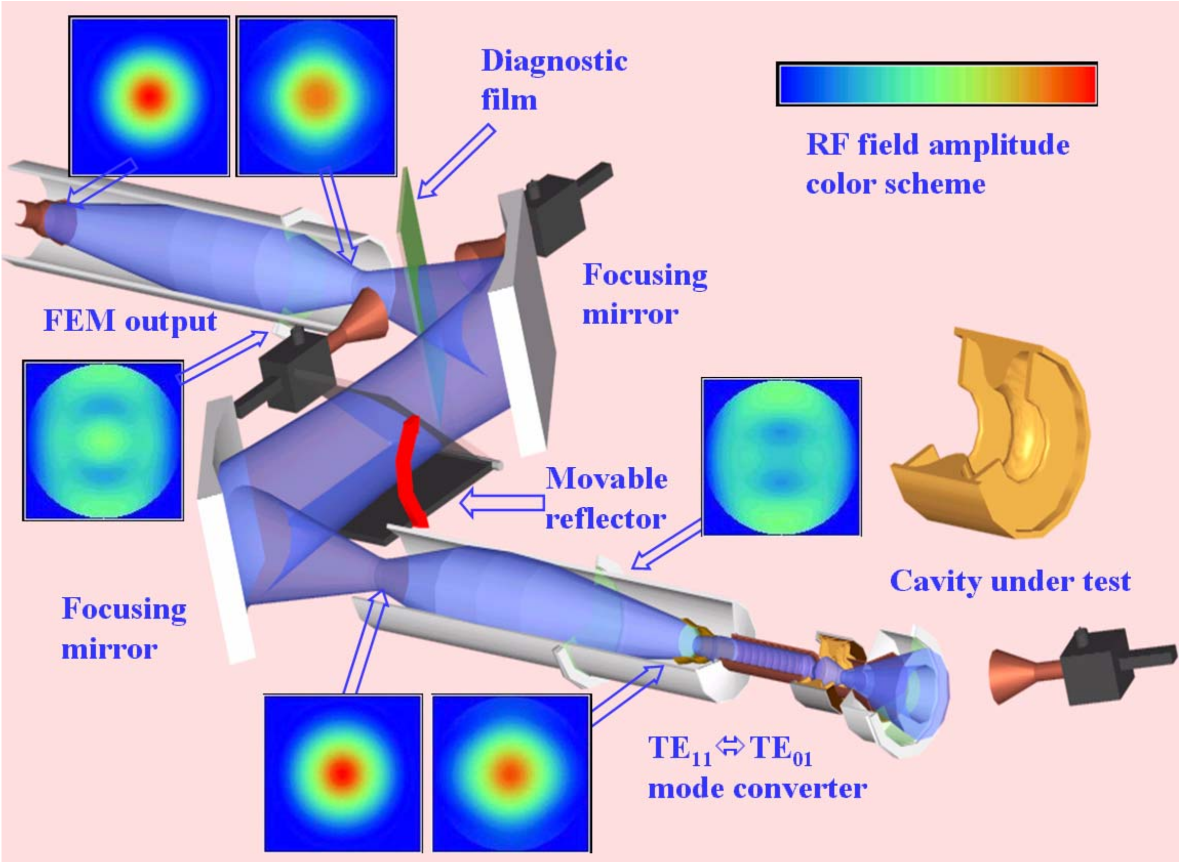

Figure 1: Overview of the quasi-optic RF transmission line.

radiation upward. It isolates the testing cavity from radiation when the radiation parameters don't match the requirements of the experiment.

The geometry of the transmission line is close to central-symmetrical one. The second oversized waveguide employing Talbot effect allows one to match the wave beam behind the second mirror and at the accepting horn as well as eliminate breakdown at the vacuum window of the test cavity. The position of the input vacuum window closer to the input horn allows us to reduce the volume of the vacuum chamber of the test cavity. The input horn with cylindrical insertion restores the pure TE_{11} mode at the input of the mode converter. The calculated transverse profiles of the RF field amplitude in several points of both waveguides are demonstrated in Fig. 1. General layout of the experimental facility is shown in Fig. 3.

A new system of optical laser alignment of the transmission line has been introduced. According to the results of cold measurements, we managed to reduce loss of the power delivered to the test cavity. The power transmission factor obtained in cold experiments was close to the designed level of 70% including all mode conversions and resistive losses.

An image of the wavebeam cross-section obtained behind the test cavity using the monitor of wavebeam position and size [4] is illustrated in Fig. 4. The intensity profile looks as well-expressed TE_{01}-like distribution.


Figure 2: Horn with cylindrical insertion.

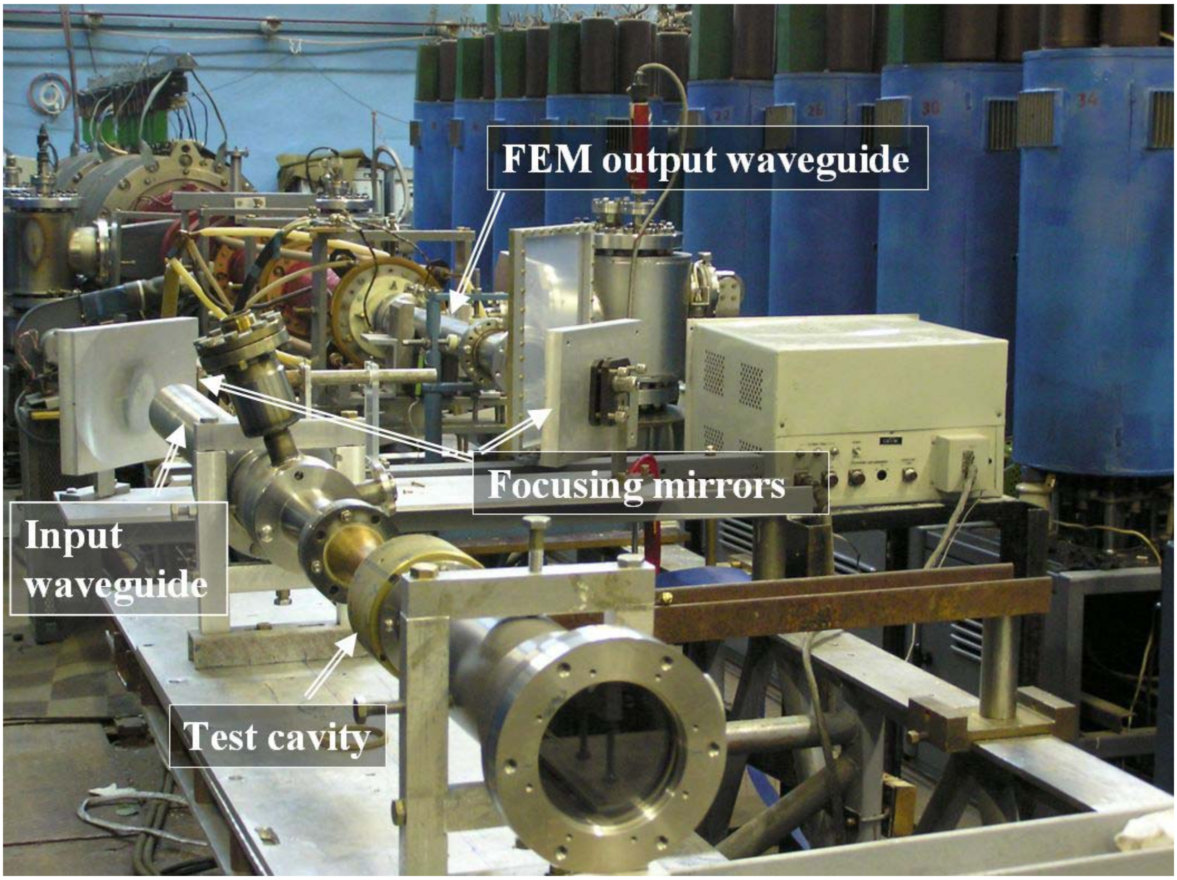

Figure 3: General view of the experimental facility.

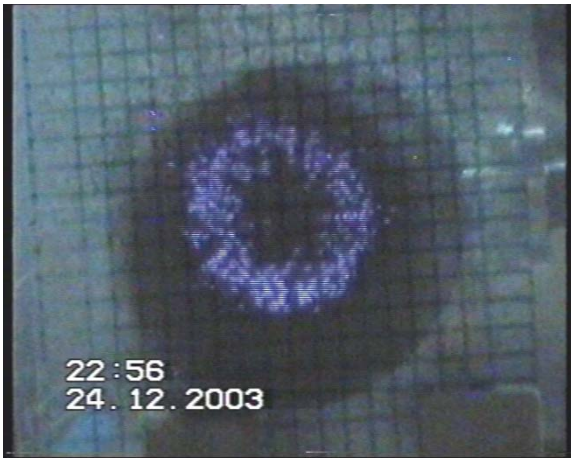

Figure 4: Cross-section image of the wavebeam behind the test cavity.

3 PROBLEM OF CENTRAL MODE SPLITTING IN BRAGG RESONATOR

According to the theory, Bragg resonators used in FEM oscillator have only one central mode with high Q-factor. But precise spectrum measurements both in cold and hot experiments show two modes with typical frequency difference of 50–100 MHz (Fig. 5). This effect is very undesirable for narrow-band loads such as RF pulse compressors or imitator of CLIC accelerating structure in our experiment.

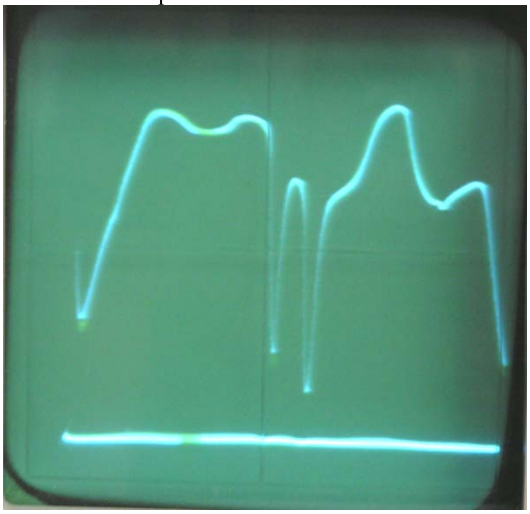

Figure 5: Splitting of the central mode of the Bragg resonator (cold measurements).

Reasons of this mode splitting are under study now. One of the possibilities is the influence of $TM_{11} \Leftrightarrow TM_{11}$ resonance not far from the operating $TE_{11} \Leftrightarrow TM_{11}$ resonance. Numerical simulation shows that this influence can be strong enough for our parameters of the resonator (Fig. 6).

Now we are developing a new type of Bragg resonator operating in $TE_{11} \Leftrightarrow TE_{11}$ reflection zone and much larger frequency distance from other possible resonances.

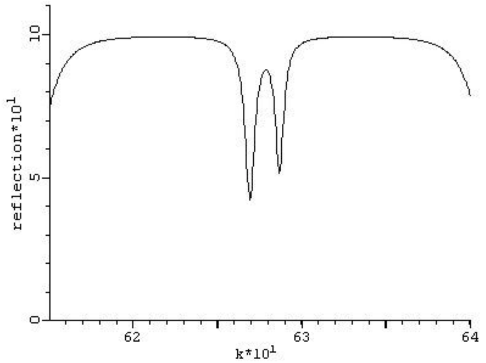

Figure 6: Splitting of the central mode of the Bragg resonator (numerical simulation).

4 DIAGNOSTIC EQUIPMENT AND DATA ACQUISITION SYSTEM

The experimental facility is equipped with 3 detectors of RF pulse which control the incident, reflected and transmitted power. The RF power and spectrum of each pulse from the required millions must be registered and stored in order to obtain correct value of the RF load at the cavity wall. We use a heterodyne spectrum meter with on-line fast Fourier transformation realized by the supplemental chip in the digital oscilloscope Tektronix TDS3032. Built-in procedure of the oscilloscope measures the spectrum width of the radiation. The oscilloscope also measures the pulse parameters of incident power. The oscilloscope sends the results to the computer via Ethernet switch using HTTP protocol. RF power of reflected and transmitted waves as well as electron beam currents and pulses of accelerating voltages are measured by the analog-to-digital converters with resolution time of 10 ns in CAMAC standard. We also have slow ADC to control the magnetic fields in the linear induction accelerator and FEM oscillator.

A distributed asynchronous object growing multi-channel system for data acquisition from the experimental facility has been built under client-server principle.

The system unites the servers of linac subsystems capable of maintaining autonomous operability of manifold equipment with different operating speed and master client computer collecting information on the whole system for subsequent processing and analysis. Such an organization allows one to reach stability relatively to faults of single servers, the flexibility, expanding capability due to the modularity principle and open system architecture.

The system of data acquisition has been built realized as several server programs and a single multi-client program employing API sockets in asynchronous regime.

Much attention is paid to modernization of power supplies both for accelerating voltages of the induction linac and focusing magnetic fields. They are very important elements of the facility in terms of providing stable parameters of the experiment during the whole statistics of 10^6 pulses.

5 CONCLUSIONS

A quasi-optic transmission line is designed for providing the high efficiency, elimination of the breakdown at the vacuum windows, possibility for full diagnostics of the incident, reflected and transmitted RF power and radiation spectrum. Multiple transformation of the transverse distribution of the wavebeam is used in the line.

A new technique of optical laser alignment of the transmission line has been introduced. According to the results of cold measurements, we managed to reduce loss of the power delivered to the test cavity. The power transmission factor obtained in cold experiments was close to the designed level of 70%.

An undesirable effect of central mode splitting in FEM Bragg resonator must be taken into account for providing the effective power transmission to narrow-band test cavity.

RF pulse diagnostic equipment and a distributed asynchronous system for data acquisition from the experimental facility built under client-server principle make it possible to register parameters of each pulse from required statistics of 10^6 pulses which is necessary to obtain correct value of the RF load at the cavity wall.

6 REFERENCES

[1] O.A. Nezhevenko, Proc. of PAC'97, Vancouver, Canada, May 1997, p. 3013.
[2] D.P. Pritzkau, Phys. Rev. Spec. Topics - Accel. & Beams, 2002, v. 5, 112002. 22 pp.
[3] J.-P. Delahaye et al., Proc. of EPAC'98, Stockholm, June 1998, p. 58.
[4] A.V. Elzhov, N.S. Ginzburg, A.K. Kaminsky et al., Nucl. Instr. and Methods, 2004, v. A528, p. 225.
[5] A.K.Kaminsky, N.S.Ginzburg, A.A.Kaminsky et al., Nucl. Instr. and Methods, 1998, v. A407, p. 167.
[6] V.L.Bratman, G.G.Denisov, N.S.Ginzburg, M.I. Petelin, IEEE J. of Quant. Electr., 1983, v. QE-19, № 3, p. 282.
[7] G.G. Denisov, S.V. Kuzikov, Strong Microwaves in Plasmas, Nizhny Novgorod, 2000, v. 2, p. 960.