STATUS OF A RADIO-FREQUENCY-BASED STREAK CAMERA WITH SUB-PS TIME RESOLUTION

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Abstract

We describe the status of our project for an RF-based streak camera. Measurements envisage the possibimity to operate within the subpicosecond domain. An evidence of a time resolution better then 0.6 ps has been demonstrated.

1 INTRODUCTION

Analysis of optical and electrical signal in picosecond and subpicosecond range is important in laser, free-electron laser, technologies, accelerator, and plasma physics. Streak cameras (SCs) are commonly acknowledgment to be the fastest instrument operating in the time domain.

Application of radio frequency (RF) magnetic field with circular polarization for deflection is an alternative technique to impart a transverse deflection to an electron beam in a streak camera (SC) [1]. A time resolution up to 700 fs on a prototype RF-based streak camera (RFC) with circle scanning was demonstrated in a previous work [2]. The GaAs photogun assisted by a chopper system that was used in Ref. [2] was changed to a photogun with transparent multi alkali photocathode. The other components of a RFC keep unchanged. Thus, a more compact RFC for analysis of the light signal with duration one RF period (350 ps) has been assembled.

The time resolution of a SC depends on many factors: initial energy spread at the photocathode, electron bunch lengthening due to space-charge forces in the gun and drift region, aberrations of optical system, speed of scanning of the beam in plane of registration, stability of the high voltage power supply, spatial resolution of a detection system and other factors.

Application of the magnetic field of an RF cavity with circular polarization for deflection of an electron beam allows to one to achieve a better time resolution than for standard SC with electric-field-based deflection system. Here, 20 kV is a practical limit of the gun voltage for conventional SC. For the RFC, one can increase the voltage in the gun up to 100 kV in order to reach smaller beam spot on the screen and to suppress the electron bunch lengthening due to space charge.

In addition, nanosecond accuracy for triggering is needed in contrast with normal SCs where triggering is often a serious problem. However for the SC with the circle scanning an analyzed signal should be less than one scanning period. Indeed, it has been proposed an idea to overcome such a circumstance (spiral scanning technique) [3]. In such a scheme, sub-picosecond resolution is kept over an acquisition interval longer than 10 ns RF spiral scanning allows keep sub-ps time resolution in a wide time interval up to 10 ns. This regime is provided by an appropriate decrease in amplitude for the RF field in the cavities of the camera and getting a spiral scanning of a beam in a plane of registration.

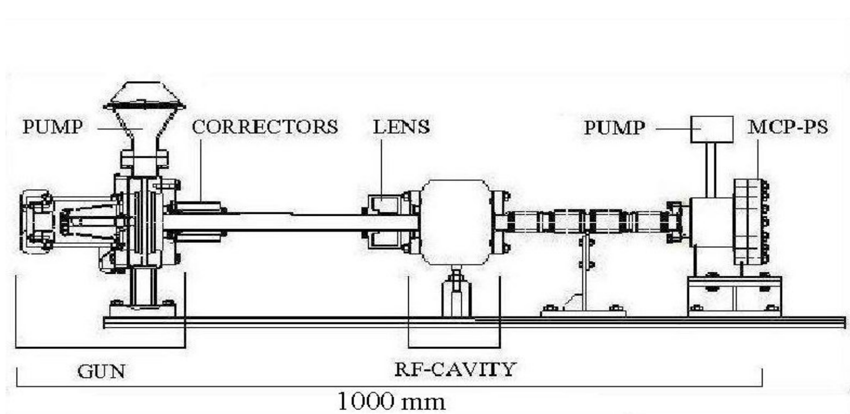

Fig.1: Scheme of the RFC.

2 EXPERIMENTAL SETUP

A scheme of the RFC is given in Fig.1. It consists of a photogun, drift tube, RF cavity, magnetic lens and detection system.

The electron gun equipped with transparent multi alkali photo-cathode, is illuminated by a 5-mW Ar laser at 500 nm wavelength and provided about 10 nA at the 80-μm diaphragm, installed after the anode of the gun. The gun works in pulse regime. (1 μs). Amplitude of high voltage is up to 35 kV at the 1-cm gap between photocathode and anode proved possible. Further raising in voltage on the photogun requires further improvement in electron gun design.

The deflecting cavity is axially symmetric and made of OFHC copper. The electromagnetic field of the TM_{110} mode is excited by magnetic loops. The magnetic fields of two mode of the cavity are orthogonal one another and can be easy shifted by π/2 rad in phase for circle scanning or by 0 rad in phase for linear scanning. The resonant frequency of each mode can be separately adjusted by means of two piston tuners.

As a result, one has a circularly rotating magnetic field with constant amplitude. The period $\tau=1/f$, where f is the working frequency. In our case $f=2856$ MHz and $\tau=0.35$ ns.

Deflected electrons passed through the drift tube and were collected by a position sensitive detector. This was a two-stage MCP coupled to a circular phosphor screen, 28 mm in diameter. MCP was fed by pulsed high voltage (-1.8 kVfor 15 ns gate) and the phosphor screen was supplied by 1.5 kV for 100 ns. Pulse duration on the MCP determined the acquisition time of the system. The image on the screen was read out by a charge coupled device (CCD) camera and acquired by computer. The overall resolution of the detector was about 60 μm (rms) mainly limited by the MCP.

3 RESULTS

We first adjusted the optics to focalize the beam as much as possible onto the screen (Fig.2a). The full width on the half height of the beam spot on the detector was about 5 pixels (Fig. 2b). Then, we adjusted the resonant frequency of each mode and the phase shift between its to attain a circlular scanning. Maximum diameter of the circular scanning (Fig. 3) was 975 pixels, i.e., D=27 mm. Consequently, one pixel is equal to 28 μm and rms of focused beam spot without scanning is 60 μm. So, we expected a time resolution $\tau=\sigma/\pi fD$ to be about 0.3 ps.

But at the maximum size of the circle scanning the full width on the half height of a cross section of the beam footprint on the screen is found about 10 pixels. This corresponds to 550 fs time resolution for the 27-mm diameter circle scanning and 2856 MHz frequency. Doubling the beam size on the screen cavity was an effect of RF field aberration and changing amplitude of its during registration time of detecting system.

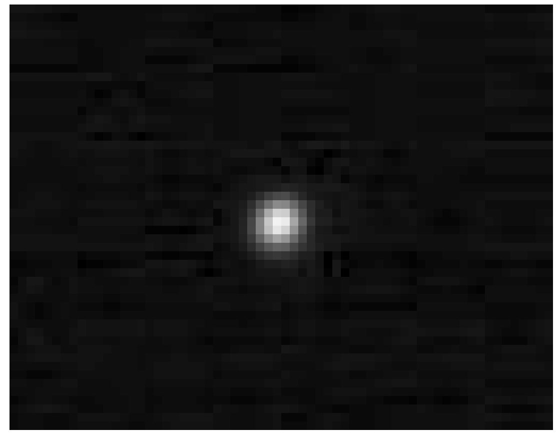

Fig. 2(a): Focused beam on the phosphor screen.

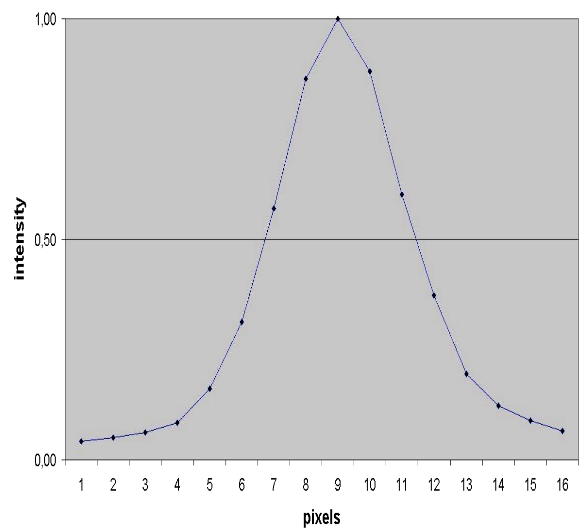

Fig. 2 (b): Cross section of the focused beam

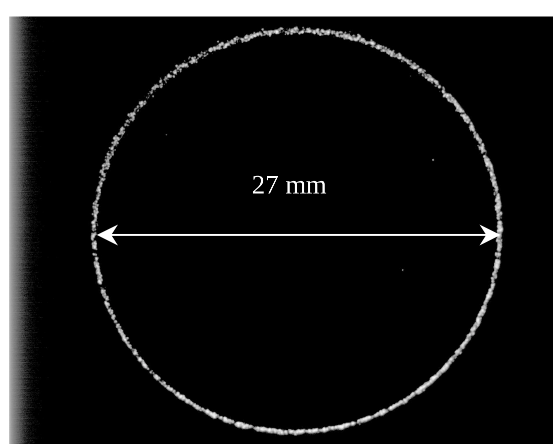

Fig. 3: Image of circular scanning.

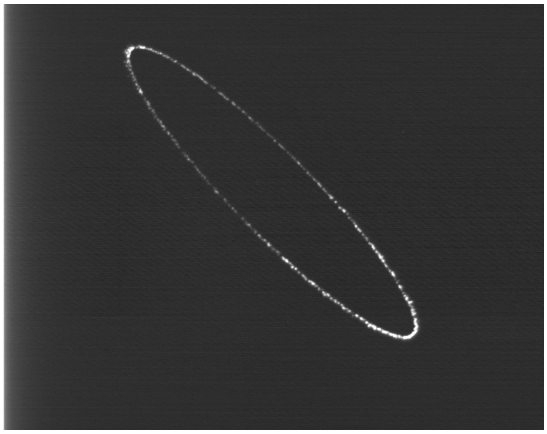

Fig. 4: Ellipsoidal scanning.

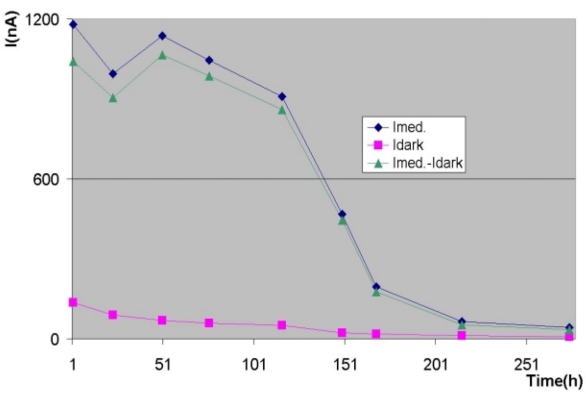

Fig. 5: Photocathode lifetime.

The lifetime of the photocathode is shown in Fig. 5. Initial quantum efficiency was about $5x10^{-4}$. The vacuum pressure at the fotocathode produced by two ionic pump was no worse than $2x10^{-9}$ Torr. Presently, the work under multialkali photo-cathode is in progress.

4 CONCLUSIONS

We have taken a step for implementation of a femtosecond time-domain streak camera. An evidence of a time resolution better then 0.6 ps has been demonstrated.

REFERENCES

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