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Diagnostic system to study sub-THz emission from open trap at strong beam-plasma interaction

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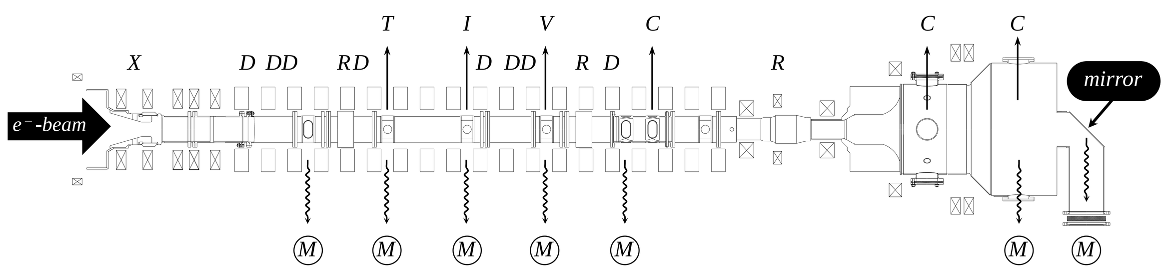
Introduction

The investigation of plasma electromagnetic emission is important fundamental task of modern astro- and plasma physics. Explanation of the solar and planet radio-emission is corresponding to plasma processes. For example solar type III radio bursts is associated with nonlinear coalescence of plasma waves in electromagnetic wave, which lead to generation at double plasma frequency $2\nu_p$, in the case of external magnetic field the radio emission is generated near the double upper-hybrid frequency $2\nu_{UH} = \sqrt{\nu_p^2 + \nu_H^2}$. There may also be radiation at the plasma frequency as the result of scattering of plasma waves on plasma density fluctuation.

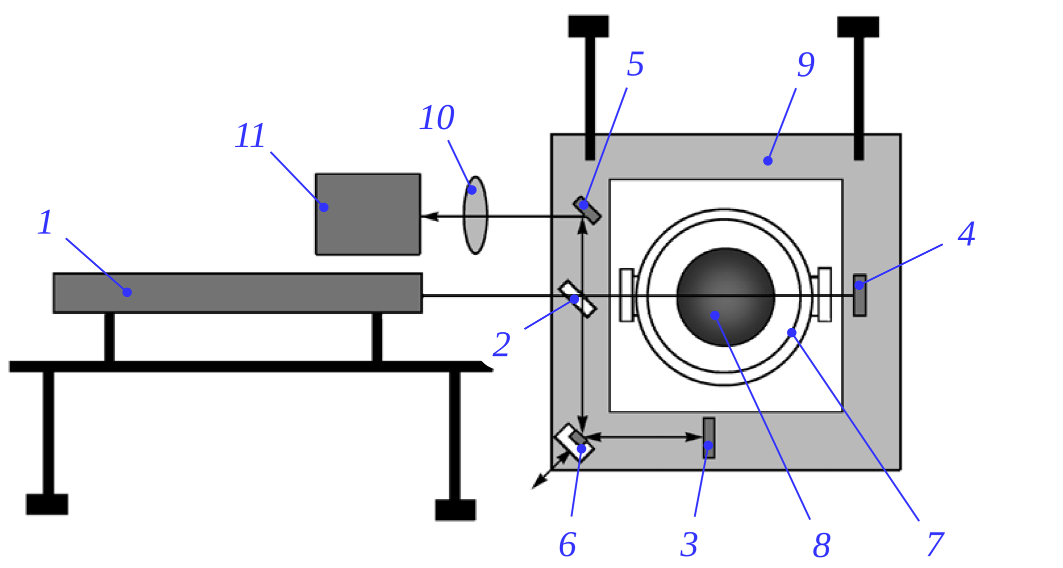
For detailed investigation of radiation generation in beam-plasma system was created special facility – GOL-3T. Schematically this facility shown at below figure. Beam electron runaway on elements of construction determent by measurement hard X-ray due to bremstrahlung. The number of plasma epithermal electrons is determined based on the amount of soft X-rays. The plasma diamagnetic pressure measured by set of diamagnetic probes located in various cross sections along the axis of the device. The electron beam currents in various parts of the device are measured by set of Rogowski coils. The energy of the injected electrons beam is calculated from the measurements of an accelerator diode voltage. The angular spread of the beam electrons and their energy distribution are measured in some additional experiments. For measurements of subterahertz radiation used radiometric diagnostics including multichannel polychromator for emission spectrum, polarimeter for measurements polarization ratio in narrow frequency band. In addition to these diagnostics set of diamagnetic loops, VUV-detectors and Rogowski coils also used.



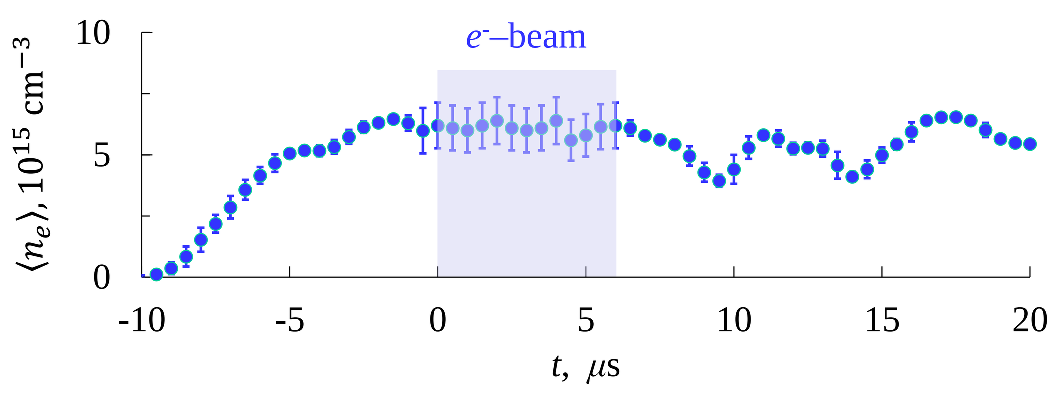
Plasma Density Diagnostics

For plasma density measurements used two laser diagnostics. The Michelson interferometer allows to obtain information about evolution of $\langle n_e l\rangle$, where l – plasma column diameter. The interferometer is based on CO_2-laser ($\lambda = 10.28\,\mu$m). The interferometric scheme has been done on damping platform in order to reduce the influence of vibrations of the system during activation of the accelerator dischargers. As a detector in the system is used *HgCdTe* photodiode cooled to LN_2 temperature (77 K), in this case the time resolution of this diagnostic is about 10 ns.The laser scattering measured the local plasma density profile. *Nd:YLF* laser ($\lambda = 1.053\,\mu$m) acts as source of scattered photons. Avalanche photodiodes are used as detectors of scattered radiation from eight spatially independent observation points along beam chord in plasma column. Registration of the scattered photons carried out at 90° to the initial direction of the incident laser beam (in this case Salpeter parameter equal to $\alpha_S \simeq 2\cdot 10^{-2} \ll 1$ (for $n_e \simeq 10^{14}$ cm^{-3} and $T_e \simeq 100$ eV) – It means that laser scattering system work in Thompson scattering regime (not collective scattering). Also Thomson scattering system can be used for measurements of plasma electron temperature.

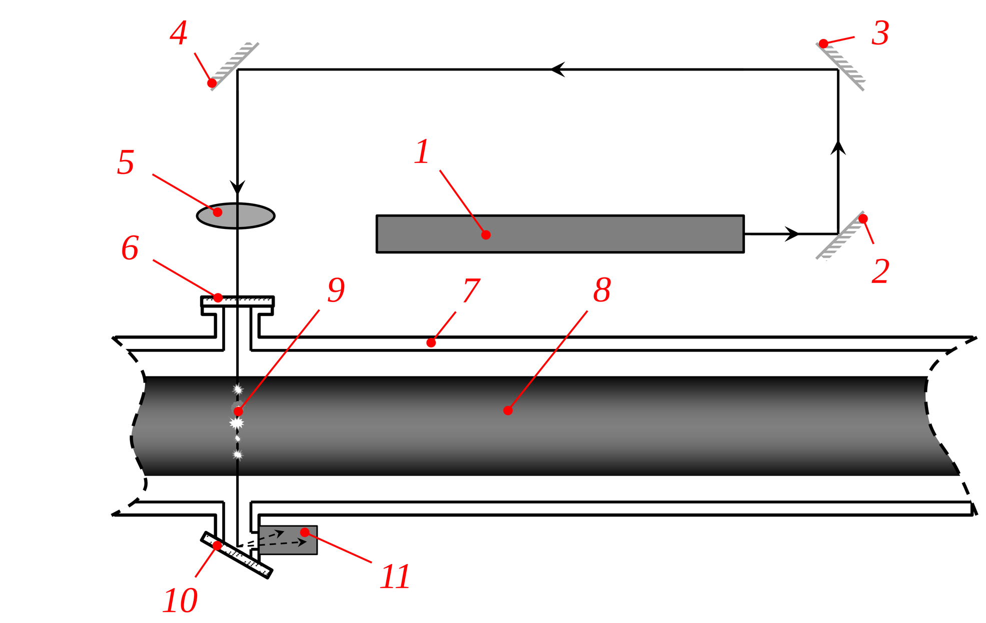
CO_2 – interferometer



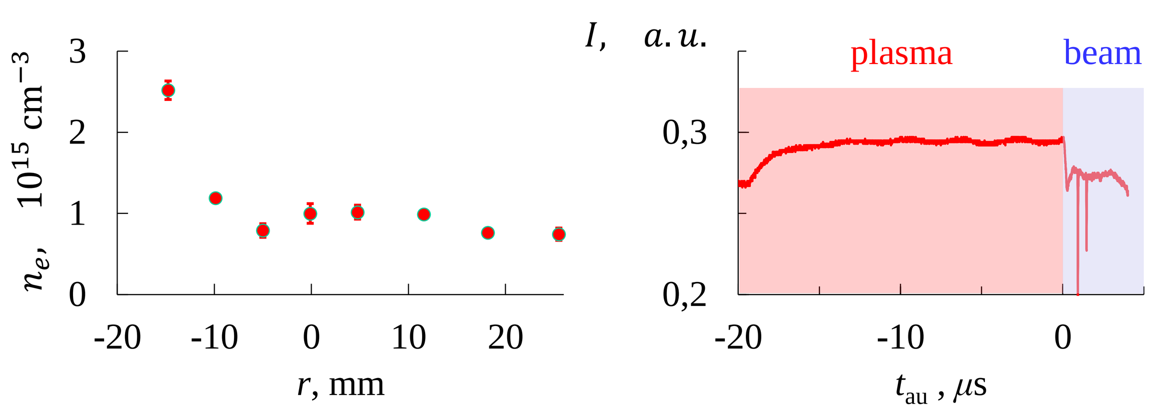
1 – CO_2-laser; 2 – beamsplitter (Al on BaF_2 substrate); 3–5 – mirrors; 6 – movable mirror on piezoceramic; 7 – vacuum chamber (windows are made of ZnSe); 8 – plasma column; 9 – dielectric frame; 10 – BaF_2 lens; 11 – HgCdTe-detector.



Thomson scattering



1 – Nd:YAG-laser; 2–4 – mirrors; 5 – lens; 6 – input window; 7 – vacuum chamber; 8 – plasma column; 9 – laser beam chord in plasma (region of laser scattering); 10 – output window at the Brewster angle; 11 – trap for scattered light.



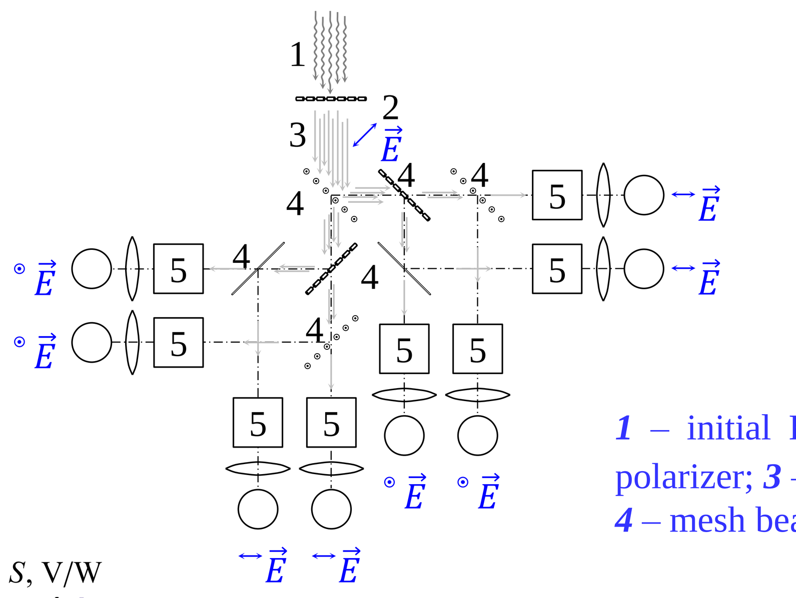
Sub-THz diagnostics

The microwave emission from the plasma column was studied in the 0.5 ÷ 5 mm band with a set of high-speed Schottky detectors covered by quasi-optical band-pass filters.

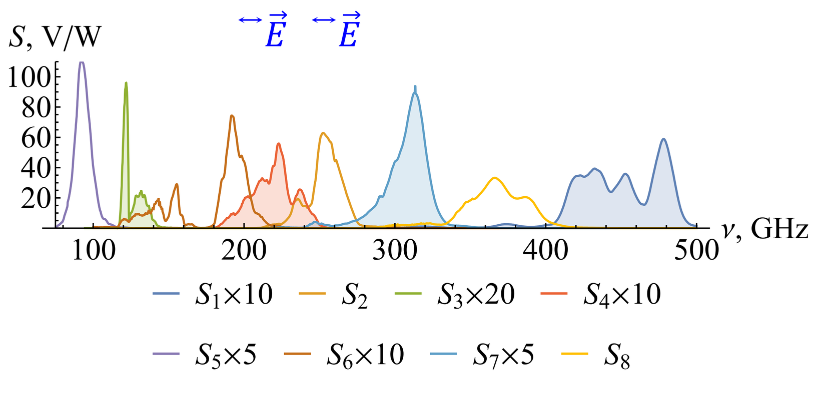
Creation technology for the quasi-optical filters was developed in Novosibirsk State University and it allowed constructing a quasi-optical system for spectral measurements in the pointed band. EM wave flow from the plasma column is divided by polarizing splitters in eight flows for the corresponding quasi-optical channels. Each flow passing through the quasi-optical frequency-selective filter is detected by a detection probes. The detection probe consists of fast Schottky detector, placed in focal plate of hyperbolic teflon lens with aperture 70 mm. Temporal resolution of the detector with ADC-200ME and ADC12500 (BINP SB RAS) is 2 ns. The filters replacement in the separate channels is used for spectral tuning the registration systems.

Directional pattern of the system is determined on the level 2° by diffraction on diaphragms installed on the way of the EM wave flows and by a collimator at the entrance of the registration systems. The quasi-optical channels consist of diaphragms and collimators and allow reaching the high attenuation of optical cross taking (up to 10^{-2}).

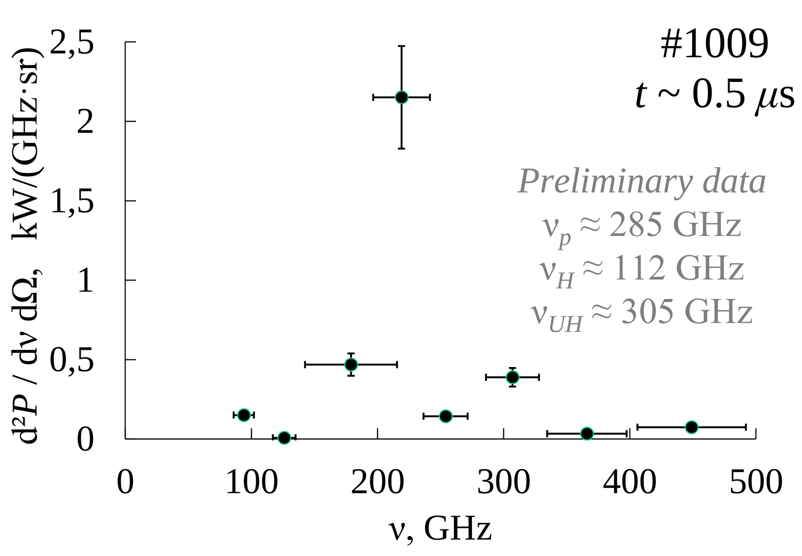
For polarization measurements used 2-channel polarimeter. The mesh beam splitter is separate the initial EM-beam on two with mutually perpendicular polarization.



1 – initial EM-beam; 2 – entrance polarizer; 3 – EM-beam with $\vec{E}\angle 45°$; 4 – mesh beam-splitters; 5 – filters.



Spectrum example



Detailed analysis of experimental data see on **Board 69**

The systems is absolutely calibrated in full working diapason by special THz facility with backward wave oscillator as a source and THz calorimeter.

Future upgrade

The first type is quasioptical superconductive hot electron bolometer. The frequency bandwidth of this device ranges from 0.3 to 3 THz. The NbN-film bridge (thickness ~ 4 nm) integrated in a planar logarithmic spiral antenna on a high-resistance silicon substrate is a sensitivity element of this device. A bolometer is mounted on the holder with silicon lens. One of the sensitivity element contact is connected to a central conductor of 50 Ω microstrip transmission line, the other contact is grounded. The bolometer itself is placed in a helium cryostat. The sensitivity element is heated to a temperature close to the critical (the required accuracy of 0.1 K), then it is shifted by direct current. Registered signal is a response to a pre-modulated incident radiation (*continuous emission can not be measured*). This signal is pre-amplified and fed to the output of the device. NEP of this device is less than 10^{-12} W/$\sqrt{\text{GHz}}$ and time resolution ~ 1 ÷ 5 ns.

The second type of new detectors are pyroelectric detectors are based on optical radiation receiver. Initially in the way of the THz-radiation beam is set radiation absorber because of heating absorber occurs reemission to an infrared spectrum area. Therefore, the frequency characteristics of absorber set the sensitivity band of detector. This type of detectors does not have time resolution and only allows overview registration emission in selected frequency band during all experiment time.

ACKNOWLEDGEMENTS

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