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EXPERIMENTS ON LONG-TIME CONFINEMENT OF FUSION PLASMA IN MAGO CHAMBER

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Abstract

The results of the last experiments on MAGO direction connected with the fusion plasma research using powerful explosive magnetic generators will be presented. The obtained results make it possible to conclude about the expediency of experiments on further compression of plasma.

Introduction

The MAGO chamber can be described as a hollow metal cylinder with a diameter of about 200 mm, with approximately the same length and with a central electrode (Fig.1) dividing the chamber into two compartments. The first compartment is the acceleration compartment, the second compartment is the fusion compartment. The compartments are interconnected with the help of an annular nozzle ~10 mm wide. In the initial condition the chamber is filled with equicomponent mixture of deuterium and tritium to the pressure of about 10 Torr.

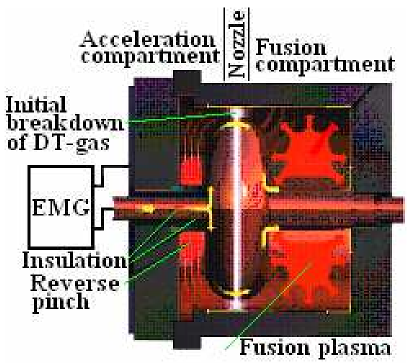

Fig.1 Physical scheme of MAGO chamber.

Initially it was assumed [1] that the operation of the chamber would have two stages. At the first stage the magnetized DT-plasma with the temperature of ~ 1 keV is formed in the second compartment of the chamber. At the second stage it is supposed to compress the second compartment of the chamber with the help of the liner driven by the current of the high-power explosive magnetic generator or with the use of an explosive charge (HE). Adiabatic heating of plasma should happen in the process of compression of the second compartment, i.e. additional rise of temperature and additional increase of neutron radiation should be observed. A great quantity of experiments has been conducted to explore the first stage of the chamber operation. The achieved magnitudes of plasma temperature and of neutron radiation yield of ~ $5 \cdot 10^{13}$ n/pls are in good agreement with the calculations. To realize the second stage of the chamber operation, it is necessary that the lifetime of plasma exceeds 10 μs. However, this time, estimated on the basis of the results from early experiments, turned out to be an order smaller than the required time. This retarded significantly the studies on the second stage of the MAGO chamber operation. The situation changed drastically due to the last three experiments called in accordance with the adopted terminology MAGO–VII, MAGO–VIII and MAGO-IX. In these experiments the electrical schemes of the measuring radiographic channels have been improved radically. As a result it has been found that in addition to short-lived (duration of ~ 1 μs) high-temperature plasma the plasma with the temperature of about 300 eV lives long enough (more than 10 μs) in the second compartment of the chamber. Having such plasma it will be quite real to achieve additional adiabatic heating of this plasma in the process of compression of the second compartment of the chamber by HE charge.

Results of the last experiments with MAGO chamber

Experiments MAGO–VII and MAGO–VIII were carried out with a discharge chamber, Fig.2, the design of which had been finalized earlier.

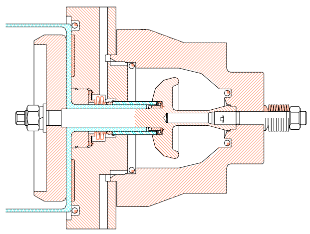

Fig. 2 Diagram of the chamber in experiments MAGO–VII and MAGO–VIII.

The device starts operating when the current increasing to ~ 1 MA for the time of ~ 100 μs flows through the central core of the chamber and generates the initial azimuthal magnetic field in the chamber. Close to the moment of field maximum the energy source, shaping the current pulse with the amplitude ~ 3,5 MA and front of about 1 μs, is connected to the electrodes of the chamber. The high voltage occurring at the input to the chamber leads to the electric breakdown in the working gas along the insulator surface. Under the effect of magnetic forces the plasma formed in the process of discharge is pulled, similar to a "snow plough", in the direction towards the chamber axis. When passing through the annular nozzle the plasma pushed out from the first compartment is accelerated to the velocities up to 1000 km/s; it forms a clot of magnetized plasma in the second compartment and the temperature of this plasma is high enough for an intensive fusion reaction. As in the previous experiments [2], the induction probes were used for the electric measurements, the scintillators and the integral activation detectors were used for the neutron measurements. Much attention was given to radiographic measurements which help to judge about the temperature of plasma, its time variations and about the spatial distribution of plasma in the chamber volume. X-ray diodes, plastic scintillators, semiconductor probes were used in combination with different radiographic filters. The distinctive feature of the above-mentioned experiments was that in the process of their preparation the measures were taken to reduce the level of electromagnetic noise in the radiographic measuring channels by several dozen times. Due to this it became obvious that in fact the duration of the radiographic signal is much longer than it was thought. Fig.3 gives a typical oscillogram of a signal from one of the radiographic probes.

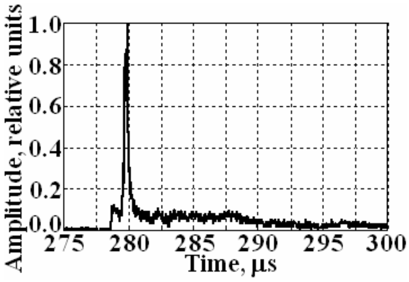

Fig. 3 Signal of the scintillation x-ray detector.

The X-ray signal consists of a short (duration of ~1 μs) pulse and of a relatively long (more than 10 μs) "tail". The obtained result became the basis for subsequent computation-theoretical and experimental studies and for engineering development aimed at a preparation of the experiments on further plasma compression. Performance of experiment MAGO-IX, in which a new chamber geometry,Fig.4, was used, became an important step in this direction. The fusion compartment of the chamber has a well-defined cylindrical shape. The dimensions of the compartment were selected with regard to the dimensions of the specific cylindrical HE charge planned to be used in subsequent experiments on further plasma compression.

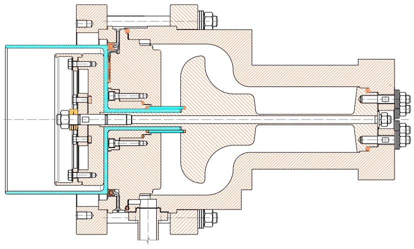

Fig.4 Scheme of the chamber in experiment MAGO-IX.

The dimensions, the configuration of the electrodes and of the inner surface of the chamber were optimized on the basis of two-dimensional MHD calculations. In addition to traditional measuring techniques a three-channel x-ray spectrometer of “DANTE” spectrometer type was used in this experiment for the first time. The presence of the x-ray “tails” in this experiment became all the more evident. In experiment MAGO-VIII the portion of energy radiated by the long-lived plasma on the “tail” of the x-ray signal was about 50%, in experiment MAGO-IX this energy exceeded 70 % of the energy radiated during the entire lifetime of plasma. Due to the data provided by spectrometric X-ray measurements the radiation spectrum was recovered and the long-lived plasma temperature was evaluated.

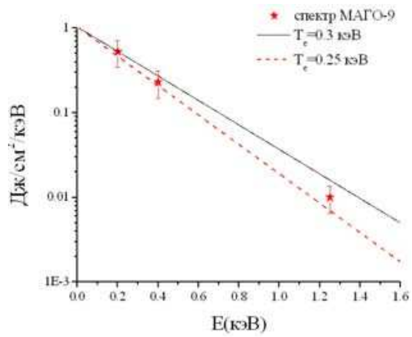

Fig. 5 Recovered spectrum of X-radiation.

Within the limits of the experimental measurements error the radiation spectrum is exponential and it testifies to the fact that the plasma temperature is within the interval from 0,25 to 0,3 keV. On the basis of the obtained data an optimistic conclusion can be drawn that the temperature of the long-lived plasma is sufficient to get the second peak of plasma temperature and the second peak of neutron radiation in the process of compression of the fusion compartment of the chamber with the use of HE charge.

References

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