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# Development of pellet technologies for tokamaks and ICF

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Since the end of 70[th] pellet injection has passed a long way from being an exotic tool for tokamaks to become one of important technologic systems on every large magnetic fusion machine and ITER. This contribution presents recent results in the field of pellet injection.

## Introduction.

During last twenty years principal technical problems of pellet injection such as high rate repetitive injection, continuous extrusion, pellet guide tube systems for HFS injections, tritium operation, doped pellets formation and so on have been solved. Much more modern problems concerning pellet injection have a physical nature:

- density transport in main plasma and divertor after pellet injection;
- ultrafast transport during pellet injection;
- formation of pellet cloud shape and its application for plasma diagnostic purposes;
- PCX diagnostics;
- runaway and supratermal electrons diagnostics;
- stratification of pellet cloud role of direction of pellet injection.

Problems with explanation and modeling of the listed physical phenomenon lead to uncertainties in R&D on pellet injection hardware and slow down a further development of this kind of plasma investigation facilities.

Present contribution is a result of several scientific teams activity working in a tight collaboration to develop the following techniques for pellet injection harware and physics:

- pellet guide systems with funnels and commutation units;

- interface unit for centrifuge pellet injector providing a small angle of horizontal pellet spreading at the centrifuge output;
- injection of minipellets with small well reproduced velocities for plasma machine with low density or very short discharges;
- application of pellet injection technique in the field of direct drive ICF projects.

**Centrifuge pellet injector.**

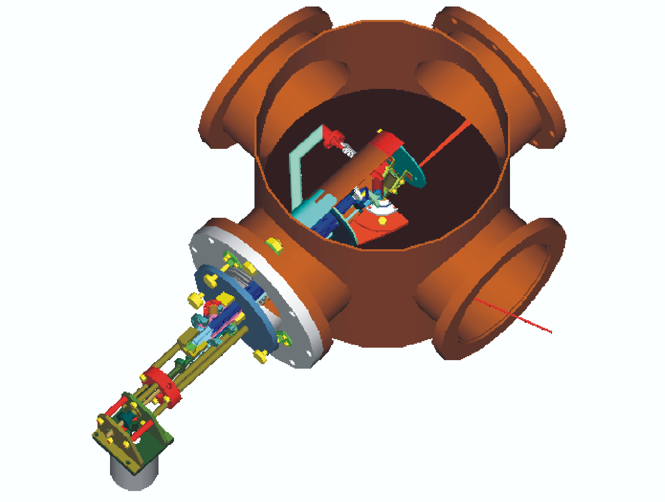

*Fig.1. 3D drawing of ITV5 centrifuge pellet injector for Globus-M spherical tokamak.*

TUAP Ltd., SPbSPU and Efremov Institute teams in collaboration with Globus-M team in Ioffe insitute have developed a new centrifuge pellet injector ITV5 for Globus-M spherical tokamak operating in Ioffe Institute. This injector can test different types of the interface unit between a pellet formation unit and an acceleration arm of the centrifuge. ITER relevant technical solutions will be tested on the centrifuge. 3D drawing of the centrifuge is presented in fig.1.

**Pellet injector for plasma systems with short discharges.**

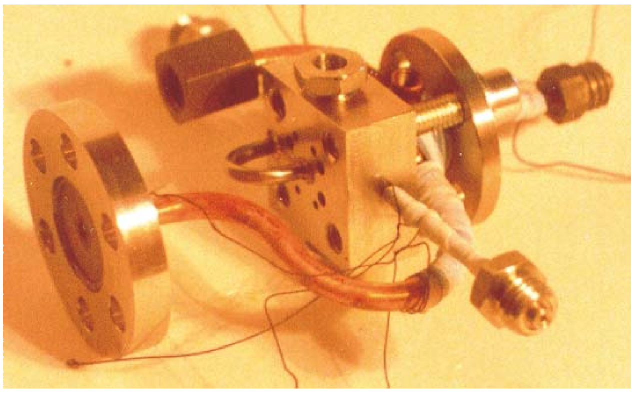

*Fig.2. Photo of pellet formation unit (extruder, acceleration unit with barrel, wired heaters and tubes for liquid helium) of gas-kinetic pellet injector ITV7 for GOL3 multiple-mirror machine.*

TUAP Ltd. and SPbSPU teams in collaboration with GOL3 team in Budker Institute have developed a new gas-kinetic pellet injector ITV7 for GOL3 multiple-mirror machine in Budker Institute. This injector produces small solid hydrogen pellets (D1x1 mm) and injects them with a low velocity (10 - 100 m/s). The pellet is used as a target for a relativistic electron beam that creates plasma in GOL3. Photo of pellet formation unit consisting of extruder and acceleration unit is presented in fig.2.

**Pellet guide system.**

TUAP Ltd. and SPbSPU teams in collaboration with TUMAN-3M team in Ioffe institute are working on a new pellet guide system (PGS2) for multibarrel in-situ pellet injector ITV4 installed on TUMAN-3M tokamak. In comparison with previous design (PGS1) a new one based on rectangular waveguide tubes, includes commutation unit, joins with NBI connection at the tokamak port and consists of easy mounted pellet guide sections. Drawing a part of PGS2 from the injector output to diagnostics chamber is presented in

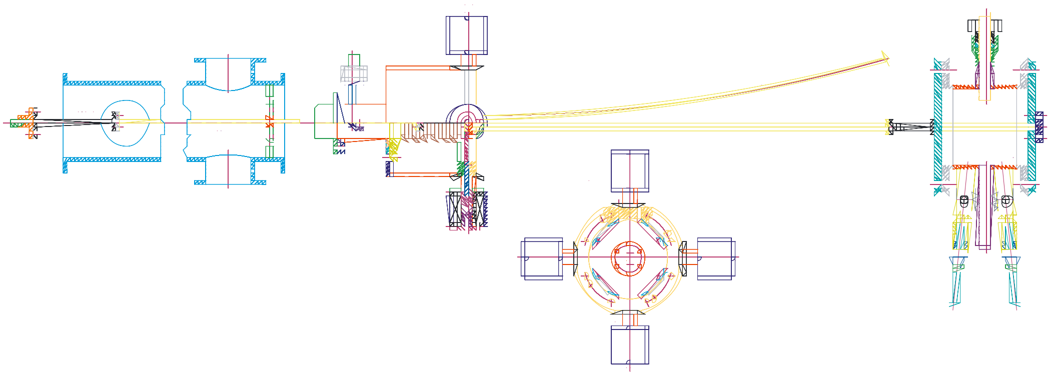

*Fig.3. Drawing of pellet guide system of ITV4 multishot in-situ pellet injector for TUMAN-3M tokamak. Pellets moves from left to right through diagnostics chamber of injector, commutation unit, waveguides (straight waveguide goes to diagnostics chamber and next to LFS injection port, curved one – to HFS injection port).*

fig.3.

The system allows to inject pellets in different trajectories and to switch the injection lines during plasma discharge in frame of 10 ms.

**Application of pellet injection technique for ICF.**

The free-standing target (FST) technologies have been developed by Lebedev Physical Institute team for 1 mm targets [1]. The next program was accepted in 2000, which is aimed at further optimization and extension of the FST technologies onto the inertial fusion energy (IFE) requirements.

A schematic drawing of “cryogenic target & sabot” assembly device is shown in fig.4. The construction includes revolving drum with special units connected at 3 of 4 drum positions, which is used to provide a repetitive operation.

Sabot loading unit is connected to the left position and provides loading of empty sabot to the drum cell. Sabots are made from magneto-insulator material. Magneto-insulator consists of polymer matrix and magneto-active additives covered by insulating layer to reduce eddy current.

Targets formation module based on FST technology is connected to the top position

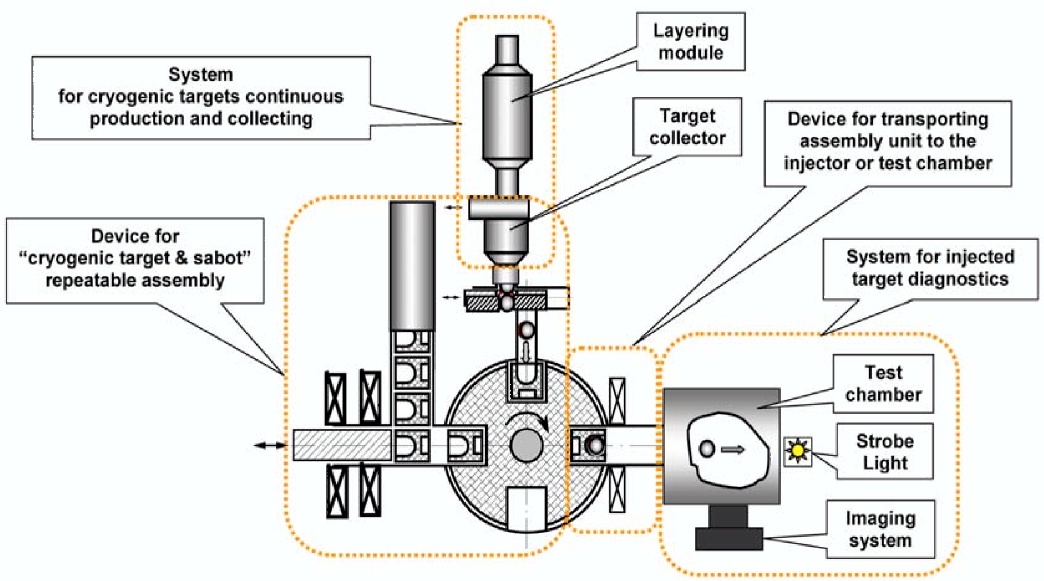


*Fig.4. Schematic drawing of the "cryogenic target & sabot" assembly device. Size of cryogenic target is up to 6 mm and velocity is about 300 m/s.*

and provides loading of cryogenic target to the sabot.

Acceleration unit is connected to the right position of the drum and provides preliminary acceleration of sabot with cryogenic target by electromagnet. After preliminary acceleration may be used pipe gun technology as in ordinary pellet injectors developed by TUAP Ltd. and SPbSPU teams.

The aim of the new project is development of IFE target factory with target injector whuch can be used as a prototype of target loading system for ICF reactor.

**References.**

[1] I.V.Aleksandrova, E.R.Koresheva, I.E.Osipov et al. Free-standing target technologies for ICF // Fusion Technol. **38 (**1), 166, 2000.