*31st EPS Conference on Plasma Phys. London, 28 June - 2 July 2004 ECA Vol.**28G**, P-1.192 (2004)*

Development of pellet technologies for tokamaks and ICF

V.G.Kapralov[1], B.V.Kuteev[3], G.A.Baranov[2], V.K.Gusev[4], V.S.Koidan[5], S.V.Lebedev[4], L.G.Askinazi[4], S.M.Egorov[6], V.V.Elagin[6], S.A.Perfiljev[2], V.V.Postupaev[5], V.N.Skripunov[2], S.V.Sergeev[6], V.A.Belopolsky[6], S.Salem[1], V.O.Muratov[6], I.V.Klotchkov[6], D.S.Moseev[6], I.P.Sharov[6], A.N.Kuznetsov[6]

[1]State Polytechnical University, St.Petersburg, Russia
[2]Efremov Institute, St.Petersburg, Russia
[3]NFI RRC "Kurchatov institute", Moscow, Russia
[4]IoffePhysico-Technical Institute, St.Petersburg, Russia
[5]Budker Institute, Novosibirsk, Russia
[6]TUAP Ltd., St.Petersburg, Russia

Introduction.

Present contribution is a result of activity of several scientific teams working in a tight collaboration to develop the following techniques and software for pellet injection [1]:

- pellet guide systems with funnels and commutation units;
- modeling of pellet evaporation, cloud formation and evolution;
- modeling of transport processes after pellet injection, including formation of transport barriers;
- 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;

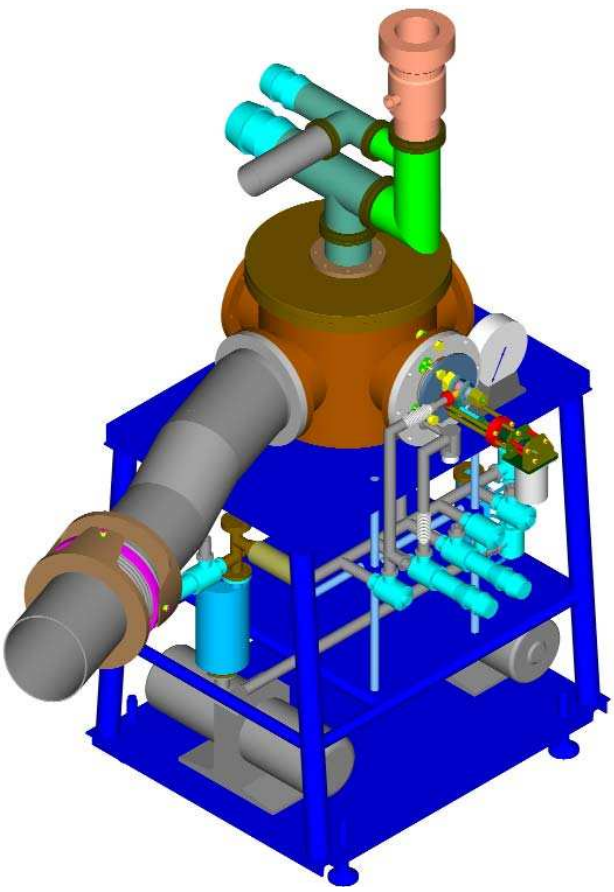

Fig.1. 3D drawing of ITV5.1 centrifuge pellet injector for Globus-M spherical tokamak.

Centrifuge pellet injectors.

TUAP Ltd., SPbSPU and Efremov Institute teams in collaboration with Globus-M team in Ioffe insitute works on the further development of ITV5.1 centrifuge pellet injector 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. Photo of the accelerating arm of ITV5.1 centrifuge pellet injector is shown on fig.2.

Fig.2. Photo of the accelerating arm of ITV5.1 centrifuge pellet injector.

As an alternative to a stop-cylinder unit is a interface unit with curved tube which is shown on fig.3. Acceleration channel of the rotating arm is curved in vertical plane at the begin. Input of the curved part placed exactly on the rotation axis. Pellets, which are initially accelerated mechanically or by gas up to 100 m/s, go through fixed tube to the input of rotating tube.

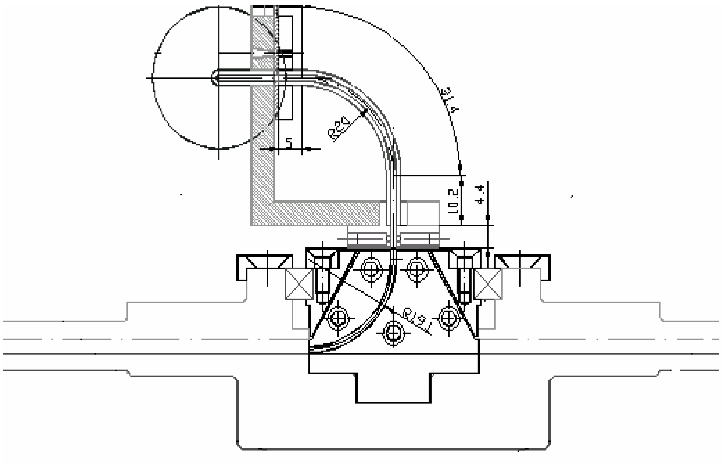

Fig.3. Drawing of interface unit of ITV5.2 centrifuge pellet injector. Rotating arm of the centrifuge has a curved part started from the rotation axis direction, this allows to avoid usage of a stop cylinder.

Pellet injector for plasma systems with short discharges.

TUAP Ltd. and SPbSPU teams in collaboration with GOL3 team in Budker Institute works on the further development a 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). Initial acceleration is mechanical (with pusher) and then low pressure gas produces final gas dynamical acceleration. The pellet is used as a target for a relativistic electron beam that creates plasma in GOL3. A strong requirement is reliable registration of pellet velocity and exact prediction

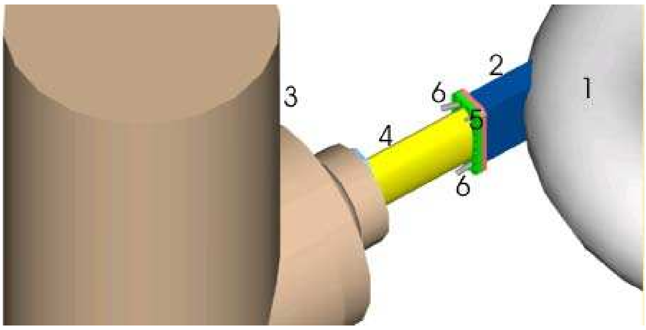

Fig.4. 3D drawing of combination pellet and NBI injection intoa one port of TUMAN-3M tokamak. 1 – TUMAN-3M; 2 – tangential port; 3 – NBI injector; 4 – elliptical connection of NBI injector to the tangential port; 5 – tube for pellet guide system connection; 6 – additional small flanges for pellet diagnostics.

a time when pellet will be on the axis of GOL3 machine to provide synchronization electron beam source and pellet injector.

Pellet and NBI injections.

TUAP Ltd. and SPbSPU teams in collaboration with TUMAN-3M team in Ioffe institute are working on a connection both ITV4 pellet injector and NBI injector to the tangential port TUMAN-3M tokamak. ITV4 pellet injector is multibarrel in-situ solid hydrogen pellet injector. NBI injector placed near to the port and connected directly to it. ITV4 pellet injector is connected to the port by PGS2.2 pellet guide system with a differential pumping. Drawing of the port connection is shown on fig.4.

Modeling of pellet injection into TUMAN-3M tokamak.

A new code for calculation of pellet ablation and plasma relaxation after pellet injection has been developed. The main motivation of the development this software was supplying pellet injection team with a tool which allows a fast calculation and analysis of current experiment during the interval between tokamak discharges. So in the code we prefer really measuring parameter instead of dimensionless values, real geometry of the tokamak and pellet injector, also we avoid time consumption iterations and fine meshes.

The code includes Parks scaling for pellet evaporation rate [2, 3]:

$$\frac{dN}{dt} = 1.08 \cdot 10^{16} n_e^{0.333} T_e^{1.64} r_p^{1.333} A_p^{-0.333}$$

Here N – number of atoms in the pellet, n_e and T_e – electron density and temperature of the plasma, r_p – pellet radius.

Depletion of plasma in case small volume of magnetic tube (center of plasma discharge) or long evaporation in the frame of the same tube (tangential injection) is taken into account according [4]:

$$Q_e^d = Q_e \frac{2\pi Rr\left(V_{Pel}\right)_r}{V_{Te} r_0^2} \left(1 - e^{-V_{Te} r_0^2 / 2\pi Rr\left(V_{Pel}\right)_r}\right)$$

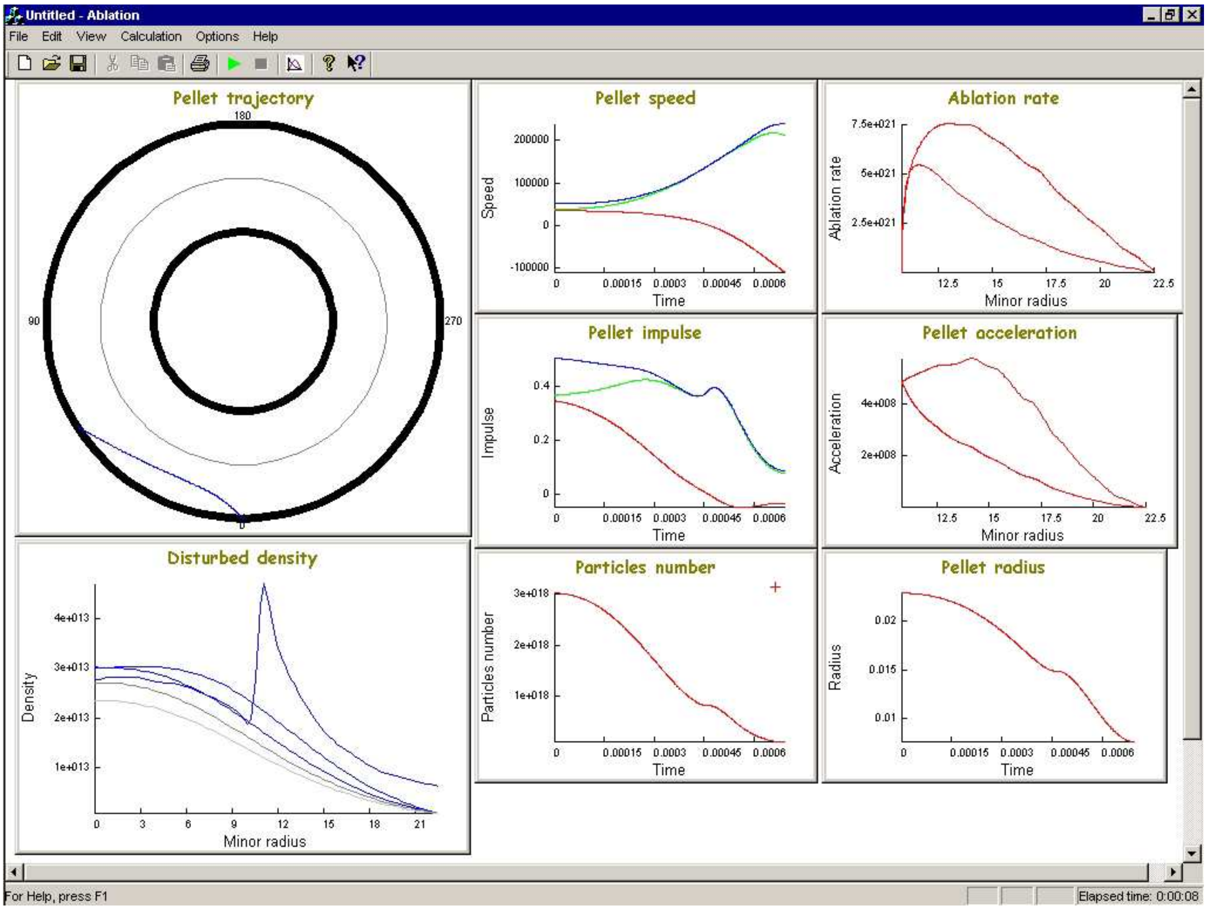

Fig.5. Output window of the code for calculation of pellet ablation and plasma relaxation after pellet injection.

Here Q_e and Q_e^d are electron fluxes on the pellet without and with depletion; $(V_{pel})_r$ – radial projection of pellet velocity.

Pellet acceleration due to asymmetric of electron distribution function in plasma with current describes as in ref. [5]:

The work was supported by RF President grant NS-2216.2003.2 and RFBR grants 02-02-17555, 02-02-17693 and 04-02-16911.

References.

1. B.V.Kuteev, V.G.Kapralov, V.Yu.Sergeev et al., 30th EPS Conference on Plasma Phys. and Contr. Fusion, St. Petersburg, 7-11 July 2003, ECA, Vol. 27A, P-2.144.
2. P.B. Parks et al., Nuclear Fusion, Vol. 17 (1977), 539
3. P.B. Parks, R.J. Turnbull Phys. Fluids, Vol. 21 (1978), 1735
4. W.A. Houlberg, S.L. Milora, S.E. Attenberger, Nuclear Fusion, Vol. 26, No4 (1986)
5. B.V. Kuteev, Nuclear fusion, Vol. 35, No 4 (1995), 431.