Concepts of Z-Pinch Controlled Fusion

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Concepts of controlled fusion:

a) **low density** and **long-living plasma** (magnetic confinement)
– tokamaks JET, (TFTR,) ITER, (EU, Japan, Canada, Australia), helical systems (Germany, Japan)
D+T, densities ~ 10^{20}m^{-3}, time of confinement ~ s

b) **high energy density** and **short living plasma** (inertial confinement) D+D

- **huge lasers** (USA-NIF, France, Japan, UK…)
  densities > 10^{30} m^{-3}, time of confinement <$10^{-14, -9}$ s
  direct and indirect drive - symmetry, ultrahigh energy electrons, fast ignition, efficiency

- or **Z-pinches** (Russia, USA) +magnetic confinement (kT)
  densities > 10^{30} m^{-3}, time of confinement ~$10^{-8, -7}$s,
  indirect drive of soft X-rays
  high energy plasma component and neutron production

Z-pinch concepts

XUV indirect drive
Z-device Albuquerque, USA
18 MA / 100 ns, double tungsten liners,
280 TW - 1 MJ soft X-ray energy per 5 ns, 15% efficiency
temperature of radiation ~ 150 eV → 250 eV (X1)

keV range of X-rays, **hot spots**
localities with temperature and density of ~ two orders higher than in other pinch plasma
→ local ignition of a few localities inside of the pinch
Linhart and Bilbao - simulations 10 MA / 10 ns
μm localities, a few % of particles

100 keV range of ions, **neutron yield** - experiments with D
plasma focus devices - PF 3 at Kurchatov Institute, PF 1000 at Warsaw (yield 10^{12} - probability 10^{-6})
Z-accelerator 10^{9-11} , MAGPIE 10^{9}, S – 300 10^{8}.

Theory of Z-pinch

total **transformation of kinetic energy into heat** (Bennett equation) chain: compressing magnetic energy → kinetic energy → heating of the pinched plasma → radiation and the stationary conditions are described by Bennett equation

hot spots and neutron production ← increase of resistance → high electric field generation → acceleration of electrons (X-rays) and ions (neutrons)

acceleration of ions and electrons
- the same mechanism at the same time ?

Today problems

XUV - Z Albuquerque, S-300
fast compression without instabilities W-liners
symmetry of radiation and pellet
high current switch – **opening switch**
direct transformation of kinetic energy into heat ?
financial support

Study of X-rays (hot spots)
higher Z elements radiation in K- and L-lines of Al, Ti, Ar→
density, temperature, **B**
problems with experiments and theory

High energy ions >100 keV
PF devices more efficient than fast Z-pinch devices
differences – time, volume, plasma density
question of B_z influence [4]

Role of magnetic field at energy transformations
ICDMP – PF 1000 and S-300 experiments
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Experiments with **thick wire** loads (+liners and plasma-sheath)
- depress an instability development
- slow down the velocity of transformations of the plasma configurations

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B_z- spontaneously self-generated at the Z-pinch implosion - consequence of the fluctuations of plasma density, implosion velocity and cylindrical symmetry of magnetic field - random orientation.

Experiments improved the **existence and transformation of B_z**:
helical structures in some phases of pinching discharges
relatively **long and stable** pinch phase
pulsation of pinch phase
”**second pinching**” of the pinch phase → hot spots
confinement or back return of the plasma exploding from the pinch

neutron yield at Al wire in the PF
neutron generation after pinch and X-ray pulse 100 ns

Influence for study of fusion:

Efficient XUV production - **depression B_z** (fast Z-pinches, influence of initial phase of wire breakdown and evaporation).

Mechanism of acceleration of electrons and ions

Conclusions

Intensive research in the field of Z-pinches
- study of dense plasma at different configurations
- complex diagnostics of single shots

International collaboration of scientists in experiments, diagnostics, simulations and theory

International financial support

General interest of representatives of human community to **solve the problem of production and consumption of energy**

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