SUMMARY OF THE SECOND INTERNATIONAL CONFERENCE ON HIGH DENSITY PINCHES, LAGUNA BEACH, CALIFORNIA, APRIL 26–28, 1989

INTRODUCTION

The conference was divided into five oral plenary sessions plus a poster session. These five sessions reviewed Z-pinch research, vacuum sparks and spectroscopy, stability, theoretical modeling, and fiber-pinch fusion. The main emphasis of the meeting was on the analysis of the X-ray emission and yield from Z-pinches and on the stability and radiative collapse. A few posters and talks were devoted to the use and analysis of dense plasma focus discharges.

More than 100 participants, one-third (34) from foreign universities, attended this conference. Many countries, including the USSR, Japan, Korea, France, Federal Republic of Germany, Poland, England, and Finland, as well as the United States, were represented. Of the 69 U.S. scientists, one-third came from industry (i.e., Maxwell Labs, Berkeley Research Associates, Physics International, JAYCOR), and the rest from universities and national laboratories [i.e., Naval Research Laboratory (NRL), Los Alamos National Laboratory (LANL), and Sandia National Laboratories (SNL)].

Z-PINCH RESEARCH

Z-pinches are important tools in such fundamental research areas as X-ray laser, material equations of state, ultrahigh B-fields, and high-density, high-temperature plasma physics. Many laboratories are currently conducting research in this field, as attested by the diversity of the countries represented at the conference.

The size of the machines varies greatly. The largest and most powerful X-ray machine in the world is SATURN, located at SNL. It is capable of producing ~500 kJ of X rays in 40 ns in experiments on xenon. Experiments on argon produced 490 kJ in 10 ns, and most of the energy ended up in the He_{α} resonance line of argon with a 10-MA current. Other Z-pinch experimental results were presented, namely, those obtained at Physics International (3.5-MA current), which evidenced an I^4 scaling of the argon K-shell yield below 2 or 3 MA, as opposed to an I^2 scaling for larger currents. At NRL, a maximum of 4.5 kJ in K-shell energies at a 1.45-MA current was obtained at a 0.41-MPa background pressure. It was also found that simple metallic wires emit intensely from microspots that occur randomly in space and time. A decrease in diameter or atomic number leads to plasma breakup instabilities.

VACUUM SPARKS AND SPECTROSCOPY

Vacuum sparks are low-voltage (<20-kV), low-energy (<2-kJ) diodes used as X-ray and vacuum ultraviolet (VUV) radiation sources. The main source of VUV radiation is an isolated, 2- to 10-μm plasma in the electrode gap. A short review of temperature and density measurement techniques was presented, and some of the techniques that are applied to microplasmas were discussed. The characteristics of these microplasmas are as follows: 2 to 10 μm in dimension, $T_e \sim 1$ to 10 keV, and $N_e \sim 10^{22-24}$ cm^{-3}. They radiate 10^{3-5} ergs within 20 to 40 ps, with an associated B-field of 10^{7-8} G. The origin of these microplasmas is still unknown (possibly electron beam/plasma interaction and current-driven instabilities, microparticle explosion, or plasma collapse followed by radiative cooling). Potential applications of microplasmas were presented (ultraviolet soft X-ray spectroscopy, soft X-ray lithography and lasers, source of multiply charged ions).

The vacuum sparks can also be used as X-ray sources to study unresolved transition arrays (as is also possible with laser plasmas). Unresolved transition arrays from cerium ($Z = 58$) and samarium ($Z = 62$) were observed at ~1 keV. The temperature of these plasmas is relatively small with respect to that prevalent in a Z-pinch.

The spectroscopy of Z-pinches is being investigated. Some of the experimental techniques for measuring the temperature and density were reviewed (e.g., tracer spectroscopy), and a modeling of lithiumlike ion lines is being developed to look for X-ray lasing transitions.

STABILITY OF THE Z-PINCH

This is one of the most important topics in the field, since it is not quite fully explained. It was agreed that stability is observed only when the current rises (slow increase of the radius) and disappears when the current levels off. This phenomenon is not understood, although several papers presented plausible explanations. Magnetohydrodynamic studies suggest that the pinch is stable below a Lundquist number of the order of 100. The temperature of the pinched plasma is obviously very important; resistive stabilization could be effective at low temperatures, as suggested by Glasser (LANL). However, viscous stabilization is ineffective at high temperature. Another explanation might be that the current is lower at sausage necks. Various calculations of the growth rate of the instability and its analysis were also presented. The $m = 0$ mode is stablized by fluid flow effects above a few hundred electron volts, whereas the $m = 1$ (kink) mode has never been observed.

THEORETICAL MODELING

The theoretical modeling of the radiation effects in the pinch is also very important. For example, Davis (NRL) showed that radiation can exceed thermal conduction as a transfer mechanism and that ionization can be a major energy sink. Apruzese (NRL) reported that K_{α} line radiation is sufficient to cool a Z-pinch within 4 ns.

FIBER-PINCH FUSION

The future of Z-pinches as thermonuclear devices and for the generation of ultra-high magnetic fields was discussed. For example, a maximum of 42 MG was achieved on the 7.5-MA pinch (proto II) at JAYCOR, with a field compression ratio of ~180 and with a 3-min repetition rate. The "unusual" stability was again noted, as well as the isolation of an on-axis fiber from the imploding plasma. Stabilization of the pinch required a field of at least 10 to 15 kG. The generation of high B-fields is of interest in X-ray laser studies, atomic physics, and equation-of-state studies.

In the field of thermonuclear fusion, some experiments were supposed to start in June 1989 at LANL on HDZP II. According to the calculations, these experiments should achieve a neutron yield of 10^{16} if the temperature is high enough (10 keV). Considering the low cost of the machine ($450 000), this would be a remarkable achievement. The previous machine (HDZP I) obtained 10^7 neutrons in 50-ns pulses, at temperatures of ~300 to 400 eV and a density of 10^{21} cm^{-3}.

POSTER SESSION

There were ~40 posters presented, some of which were devoted to the study of the plasma focus. Although it was invented almost 20 years ago, plasma focus is of current interest both in fundamental (study of microplasmas) and applied research (X-ray irradiation machine and neutron production machine for radiography), and has apparently not been ruled out as a fusion machine.

Fundamental studies on the plasma focus, presented by Choi (Imperial College) and Yokohama (ILE, Osaka), were devoted to electron beam studies and to the production of deuterons, both at low and high pressure. Some applications of the plasma focus were presented by a German team from Aachen. Two areas were investigated in collaboration with industry: use of the plasma focus for soft X-ray imaging microscopy and for lithography. Their system is optimized for the emission of line radiation of nitrogen VII at 2.48 nm with a total energy of ~200 mJ in that line. X-ray lithography is developed for operation with a 2-Hz repetition rate and achieved a resolution of 0.3 μm.

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