QAIS – Quick-access information system database of CSIR

In his letters Mr. Jain, a science writer, has been bringing to the attention of *Current Science* readers the Indian efforts in science in the media and the roles and support envisaged from the institutions and individuals. In early 1990 CSIR headquarters created a database QAIS especially meant for reference by the media people while writing their essays and reports. It appears that CSIR has used dBase4 software and collected the data regarding CSIR laboratory projects, the scientists and their track records to store in QAIS database.

This writer had an occasion to see a demonstration of the database at CECRI, Karaikudi, in 1991 and enjoyed an itinerary to several CSIR laboratories to have a glimpse of the S&T activities without much ado! Some of the comments I had raised to Prof. S. K. Joshi regarding the database are recalled here.

The following questions may be pertinent to probe:

1. What is the role of cellulose material and magnetic tapes/cassettes in data storage and dissemination?
2. What is the data-handling strategy foreseen, with the information available in Research Council Meeting Reports, Annual Reports and QAIS input? What is the strategy in organizing the time schedule of scientists while supplying the input for several meetings, publication activities and database activities like QAIS? In this process, one may expect considerable saving in the time and effort of the scientists. How about electronic publication of Annual Reports?
3. Whether Annual Report publication is archival or not? What is the guarantee that a student/research worker will have an access to the complete collection of CSIR annual reports in at least 'few' labs. Browsing through several reports in print can be avoided when the QAIS database is current, comprehensive and concrete.
4. What about a programme of collecting the antiques of Annual Reports from institutional/personal sources to create repositories of these and similar documents?
5. Is there a possibility of creating a CSIR corner in laboratories to project organizational thrust with national interest as the highest priority and with wealth as the bottomline?

I feel it is worth conveying my views on this initiative. There is lot of scope for improving this database with the active participation of scientists. One may recall the aim of UNESCO's General Information Programme: 'the increased participation of scientists in the development and use of information systems, with particular attention to the involvement of scientists in the evaluation, compaction and synthesis of scientific information and data'. I can imagine the amount of labour involved in building up the database by the scientific community in CSIR laboratories. Databases like QAIS can serve the useful purpose only when the S&T community has free access and appreciation for the effort in updating the data by the scientists themselves. After all, a database has to be dated!

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Non-neutral plasmas

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Plasmas are traditionally defined as macroscopically charge-neutral collection of electrons and ions, exhibiting collective phenomena because of the long-range nature of the Coulomb interaction. The essential signature of plasmas is collective effects; hence, the ambit of the definition should embrace a wider variety of charged-particle ensembles, not always charge-neutral.

The physics of single-species plasmas has recently emerged as a novel subdiscipline of plasma physics. Such ensembles would obviously carry a net charge and consequent internal electric fields. The tendency for expansion due to mutual repulsion between the charges is balanced by the spinning of the whole ensemble in a magnetic field because of the electric drift with velocity $\mathbf{E} \times \mathbf{B}/B^2$. Linear devices which trap ensembles of single species are based on the Penning traps, originally designed to trap a few particles and extensively used by chemists to make atomic measurements on freely suspended single particles. These modified Penning traps can confine plasmas of electrons[1], positrons[2] or ions[3].

The confinement properties of Penning traps derive from the powerful constraint that the canonical angular momentum, which is the sum of the magnetic angular momentum and the mechanical angular momentum, is a conserved quantity. The magnetic angular momentum, given by $\mathbf{r} \times e\mathbf{A}/c$, where $\mathbf{A}$ is the vector potential of the uniform solenoidal magnetic field, is proportional to the summed square of the radial positions of the electrons and, usually, is much larger than the mechanical component. The invariance of the magnetic angular momentum, in the absence of external torques, means that the radial positions of electrons cannot change and if some electrons are lost from the trap, the rest of the electrons would get even more closely bound to the axis.

This happy situation results in excellent confinement of the non-neutral plasmas[4], lasting even for days together, never achievable for neutral plasmas, where electrons and ions can diffuse out in pairs, conserving the magnetic angular momentum. It is, in fact, such long-term confinement which has made possible the observation of crystallization of ions due to transition to the strongly coupled plasma state[5].

The confinement theorem based on symmetry, naturally, breaks down in the presence of small azimuthal asymmetries, inevitable in any practical device, in spite of the extreme care taken to avoid them. The effect of deliberately introduced electrostatic asymmetries has recently been studied[6] at the University of California, Berkeley, and it appears that they do not cause instantaneous plasma loss, as was suspected earlier. Since the angular momentum of these plasmas need not be conserved, the principle earlier applied to prove confinement may not apply in this case. They have shown that the area enclosed by the precession of the asymmetric plasma around the axis is a new adiabatic invariant. These asymmetric equilibria seem to be understandable in terms of a maximum-energy principle proposed by O'Neill[7].

Non-neutral plasma confined in toroidal traps are naturally subject to the problem of azimuthal asymmetry. Budker[8] had shown that the natural tendency of single particles to be lost from toroidal magnetic traps can be overcome by spinning the particles around the minor axis using an electric field along the minor radius. The latter can be self-consistently generated by confining a single-species plasma of appropriate charge density. Early theoretical work on toroidal electron clouds has shown the existence of equilibrium with closed drift surfaces under very general conditions. A series of recent experiments at IPR on low-aspect-ratio toroidal electron clouds[9] have proved the validity of many of the basic concepts, like the existence of an equilibrium, good confinement properties, toroidal effects, etc.

Toroidal particle traps with deep potential wells associated with the space charge fields and the possibility of electrostatic trapping of particles of opposite charge have led to many interesting concepts, e.g., the electrostatic thermonuclear fusion reactor[10], heavy ion accelerator[11], source of highly stripped heavy ions[12], and high-current beam sources[13] like modified betatron and stellatron. The concept of a totally non-neutral ion torus – where high-energy ions are confined by their own space charge field – may, due to relatively low transport losses compared to the conventional neutral plasma, lead to an ideal thermonuclear reactor, though this idea requires further quantitative examination.

The conventional scheme of electron injection used in all the earlier experiments was the so-called inductive charging process, in which a flux tube initially loaded with electrons as it enters the inductor, would transport a current of electrons in the direction of the Poynting vector if the magnetic field were to increase. This scheme is inherently pulsed and is not suitable for the applications mentioned above. In addition, electron losses cannot be compensated by injection of extra electrons. Most of these drawbacks vanish if injection can be done in a steady magnetic field.

An alternate, primarily steady-state injection scheme free from the above drawbacks has been experimentally realized as reported in a recent publication from the Institute for Plasma Research[14]. The technique utilizes an internal electric field produced by image charges generated on the walls of the torus by an electron stream subjected to natural toroidal drift The electric field modifies the particle trajectories into self-confining ones. The asymmetry of the potential profile formed with the positively biased inner wall provides a natural mechanism for purging of the ions created by ionization of the background gas. By this technique, a steady-state electron ring was formed in a torus. Another novel observation is the appearance of peak cloud potentials exceeding the electrode potential on the injector, which is indicative of particle transport due to collective processes.

The electrically charged fat electron rings realized in these experiments have interesting similarities to and differences from neutral plasma toroidal current filaments used for confining hot plasmas in thermonuclear research[15]. Capacitance effects replace inductive effects, image charges replace image currents, inward shift replaces outward shift, d.c. electric fields take the role of equilibrium vertical magnetic fields, Brillouin limit replaces the equilibrium β limit, vortex formation replaces magnetic inland formation, and so on. Many of these effects still remain to be explored. Another point to note is that the toroidal trap confines particles only through adiabatic invariants which can be broken by various resonant effects. One would thus expect to see interesting stochastic transport phenomena in the toroidal experiments.

1 Malmberg, J and Driscoll, C. F, *Phys Rev Lett*, 1980, **44**, 654
2. Surko, C. M, Leventhal, M and Passner, A, *Phys Rev Lett.*, 1989, **62**, 901
3. Gilbert, S., Bollinger, J and Wineland, D, *Phys Rev Lett*, 1988, **60**, 2022
4 O'Neill, T. M, *Phys Fluids*, 1980, **23**, 2216
5 Wigner, E., *Trans Faraday Soc*, 1938, **34**, 678.
6. Notte, J, Peurrung, A J. and Fajans, J, *Phys Rev. Lett.*, 1992, **21**, 3056.
7 O'Neill, T. M and Smith, R A, *Phys Fluids*, 1992, **B4**, 2720.
8 Budker, G I, in *Plasma Physics and The Problem Of Controlled Thermonuclear Reactions* (ed Leontovich, M A), 1st edition, 1961, p 78
9. Zaveri, P. *et al.*, *Phys Rev. Lett.*, 1992, **68**, 3295
10 Janes, G S *et al*, *Phys Rev*, 1966, **145**, 925
11. Daugherty, J D *et al.*, *Phys. Rev. Lett*, 1968, **20**, 369.
12. Ishizuka, H. *et al*, *Phys Rev Lett*, 1984, **53**, 266
13. Deniz, A. V., *J. Appl Phys*, 1991, **69**, 1151.
14 Khirwadkar, S. S, John, P. I, Avinash, K., Agarwal, A. K. and Kaw, P. K., *Phys Rev Lett*, 1993, **71**, 4334
15. John, P. I, *Plasma Physics and Controlled Fusion*, 1992, **34**, 2053

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