P. S. Goyal (Inter University Consortium for DAE Facilities, Mumbai) gave a talk on anomalous thermal properties and tunnelling states in solids with a specific example of mixed salt system of ammonium and alkali iodides which show non-Debye specific heat behaviour. The results of neutron scattering and specific heat measurements on these mixed salts were presented.

S. Mazumder (CMPD, BARC) highlighted that a scaling law different from those observed in the case of binary alloys, is valid in describing the temperature-dependent phase separation behaviour of a multi-component alloy like maraging steel.

P. Ch. Sahu (MSD, IGCAR) described the laser heated diamond anvil cell technique and discussed its importance in material synthesis with illustrations from his own work in Japan.

The first tutorial session on Experimental Techniques: Characterization of materials was coordinated by S. C. Gupta (CMPD, BARC). He briefly described the various techniques like STM, AFM, and CCD-based X-ray imaging. A. Sinha (CMPD, BARC) discussed in detail his set-up of CCD-based X-ray imaging for both normal and high pressure applications. N. Venkatramani (Advanced Centre for Research in Electronics, IIT, Mumbai) showed with various illustrations the potentials of Scanning Probe Microscope as a tool to characterize materials. He mentioned that atomic scale resolution is possible in the AFM and a resolution better than SEM is possible in SPM. He stressed the fact that SPM imaging has reached a high degree of reliability and is an important technological tool, specially for storage media, profilometry and as a tribological device. G. Raghavan (MSD, IGCAR) discussed the characterization of interfacial evolution in film multilayers. He pointed out that the evolution of different phases in heat treated film multilayers involves issues related to interdiffusion and microstructure.

The tutorial session on Data Processing and Scientific Visualization (coordinated by B. K. Godwal and R. Mukhopadhyay, from CMPD, BARC) was an attempt to bring about an interaction between the physicists and the computer scientists. As the basic purpose of scientific computing is to gain an insight into the problem that is being probed, it was felt that a session based on such interaction will be useful. B. S. Jagadeesh and S. K. Bose (Computer Division, BARC) enlightened the participants through their detailed lecture-cum-demonstrations on data processing and scientific visualization.

J. Jayapandian (MSD, IGCAR) highlighted the novel design concepts in PC-based integrated data acquisition and control systems. He described various novel interfacing design techniques for automation in industries and laboratories. He stressed that such indigenous approach will save a good amount of foreign exchange.

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RESEARCH NEWS

Guides for neutral atoms

K. R. Rao

Atom optics involving cooling, trapping and manipulating neutral atoms is an active field of research currently[1]. The cold trapped atoms are generally held in magneto-optic traps isolated from nearby material containers under ultra-high vacuum conditions. In order to transport the atoms over some distance, several types of devices are being developed.

It is well known that light can be guided through fibre-optic strands[2] by total internal reflection and that thermal and cold neutrons can be guided through neutron-guides[3] by total external reflection. Hollow optical fibres have been proposed for guiding neutral atoms[4] by evanescent reflection.

Two investigations have recently been reported; one dealing with an experimental demonstration of guiding neutral atoms by specific magnetic configurations and another dealing with a theoretical proposal for collimating neutral particles by a magnetic mechanism.

Denschlag *et al.*[5] have demonstrated a new technique based on magnetic trapping potentials created by a thin current-carrying wire to guide and transport neutral atoms. Two variants of magnetic field/guiding configurations were investigated: (a) In the first configuration called 'Kepler' guide, a current of nearly 1 amp was passed through a wire and the magnetic field surrounding the wire acted as the trapping and guiding field. (b) In the second configuration called 'side' guide, the current-carrying wire was placed in a homogeneous biasing magnetic field normal to the wire. In this configuration the circular magnetic field around the wire gets cancelled by the biasing field at a specific distance from the wire; hence one finds a line/tube with minimum magnetic field running parallel to the wire from which magnetic field increases in all directions and this line/tube acts as the trapping and guiding field. Figure 1 *a* shows the two guides schematically.

The interaction of atoms possessing a magnetic moment $\boldsymbol{\mu}$ with a field $\mathbf{B}$ is given by $-\boldsymbol{\mu}\cdot\mathbf{B}$. If $\boldsymbol{\mu}$ is parallel to $\mathbf{B}$ and $\boldsymbol{\mu}\cdot\mathbf{B} > 0$, the atoms are in a high-field-seeking-state and they get trapped at the surface of the current carrying wire in the 'Kepler' guide. On the other hand, those atoms with $\boldsymbol{\mu}\,\mathbf{B} < 0$ are in a low-field-seeking-state and they get trapped to the line/tube near the current carrying wire in the 'side' guide.

In the experiments carried out by Denschlag *et al.*[5], nearly a million cold lithium atoms were released in a pulse from a magneto-optic trap on to a tungsten wire 50 µm thick and 10 cm long. The wire carried a current in the range 0.5 to 1.0 amp as per the requirements of experiments. Depending on the two guide configurations chosen, the guiding potential helped to trap the atoms which were in the appropriate spin state. The radial and spatial distributions of atoms were measured at various guiding/trapping times by imaging the fluorescence from the atoms using a CCD camera.

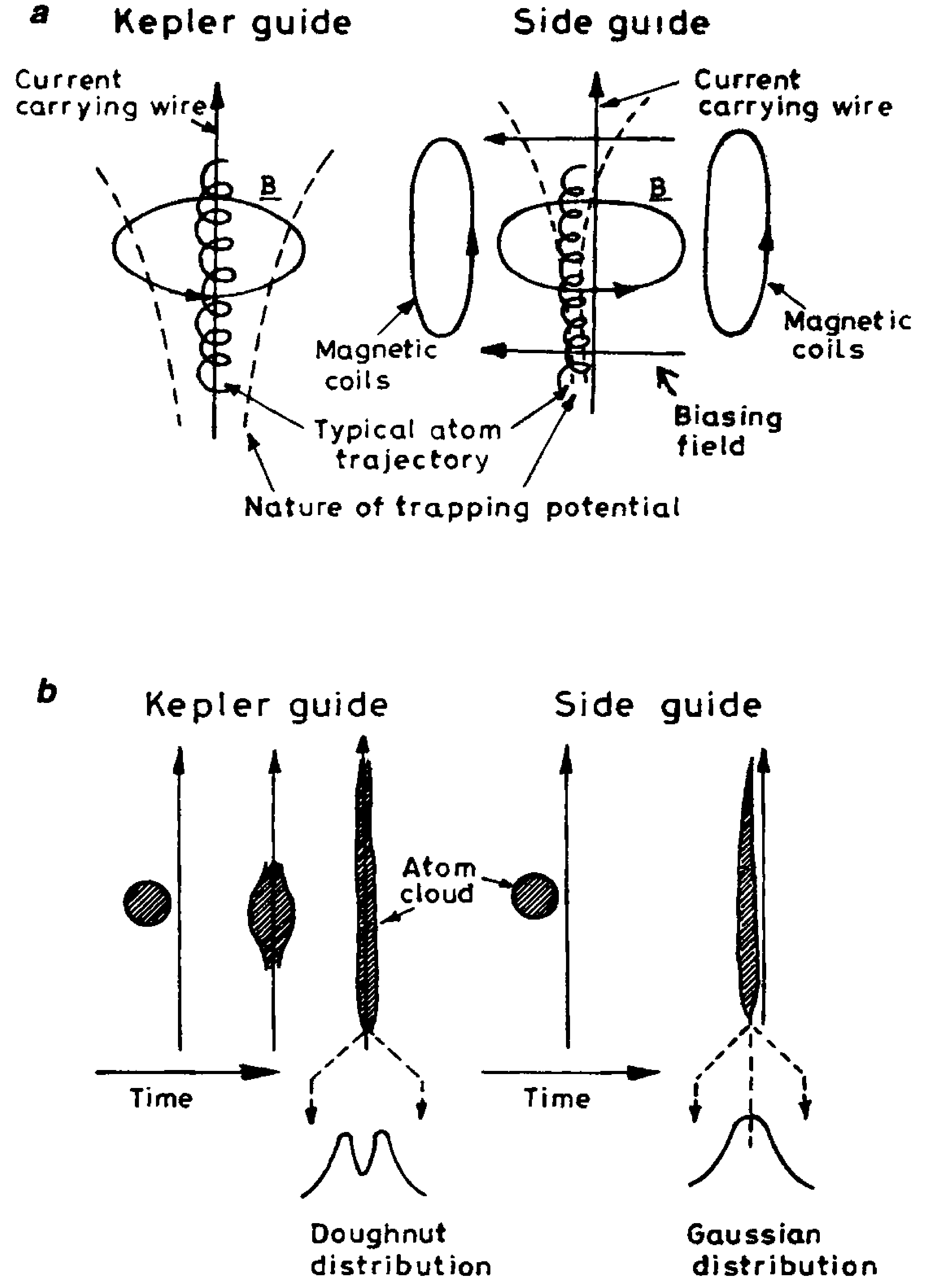

Figure 1. *a*, Schematic lay-out of 'Kepler and 'side' guides; *b*, Time-dependent axial and radial atomic density profiles in 'Kepler' and 'side' guides.

The experiments showed that about 10% atoms released from the magneto-optic trap get bound to the wire in the 'Kepler' guide or to the magnetic potential line/tube in the 'side' guide. The associated cloud of atoms expands along the wire/tube as a function of time and hence guided as shown schematically in Figure 1 *b*. The measured transverse atomic density profile around the wire indicates that in the 'Kepler' guide it is in a doughnut shape whereas in the case of the 'side' guide it is a gaussian.

According to Denschlag *et al.*[5], the 'side' guide is expected to provide a promising technique for future applications in atom optics for beam splitters, interferometers and complex matter wave networks.

Yukolov and Yukolova[6] have shown that a magnetic mechanism can be used to form directed/collimated beams of neutral particles with strong acceleration, when the particles are polarized at some initial time and subjected to specific magnetic field configurations.

The basis of this mechanism originated by considering the evolution equation of neutral particles of mass m and magnetic moment μ given by,

$$\frac{d^2R^\alpha}{dt^2} = \frac{\mu}{m}\mathbf{S}\cdot\frac{\partial \mathbf{B}}{\partial R^\alpha}(\alpha = x, y, z), \qquad (1)$$

$$\mathbf{R} = \{R^x, R^y, R^z\}$$

with initial co-ordinate R_0 and velocity $\dot{R}_0$. The average spin $\mathbf{S} = \{S^x, S^y, S^z\}$ satisfies the equation,

$$\frac{d\mathbf{S}}{dt} = \frac{\mu}{\hbar}\mathbf{S}\times\mathbf{B}. \qquad (2)$$

The magnetic field $\mathbf{B}$ is considered to be made of two fields $\mathbf{B}_1$, a quadrupolar field and a second transverse time-dependent field $\mathbf{B}_2 = B_2h(t)$. $\mathbf{B}_1 = B_1'(R^x\mathbf{e}_x + R^y\mathbf{e}_y + \lambda R^z\mathbf{e}_z)$. For the specific case of the anisotropy parameter $\lambda = -2$, Eq. (1) and eq. (2) are recast in the form,

$$\left.\begin{aligned} \frac{d^2r}{dt^2} &= \omega_1^2(S^xe_x + S^ye_y - 2S^ze_z) \\ \frac{dS}{dt} &= \omega_2\hat{A}S \end{aligned}\right\} \qquad (3)$$

where ω_1 and ω_2 are characteristic frequencies of the space and spin motions, defined by $\omega_1{}^2 = (\mu B_1'/mR_0)$, $\omega_2 = (\mu B_2/\hbar)$ and $r = (R/R_0)$ For further details see ref. 6. ω_1 and ω_2 are such that $|\omega_1/\omega_2| << 1$ in order to fulfil the criterion of slow space variation of magnetic fields involved in obtaining eqs (1) and (2) under semi-classical approximation. From this it is concluded that the space variable $\mathbf{R}$ is slow compared to the spin variable $\mathbf{S}$. Solution of the eq. (3) under this condition leads to the equation,

$$\frac{d^2r}{dt^2} = \langle\omega_1^2(S^xe_x + S^ye_y - 2S^ze_z)\rangle. \qquad (4)$$

If the case of the spin polarization, $S_0{}^x \neq 0$, $S_0{}^y = S_0{}^z = 0$ is considered, one can discuss the state of motion of polarized neutral particles when they are neither trapped nor when they escape in all directions being not confined. Yukolov and Yukolova have analysed the situation and arrived at some interesting conclusions:

- *the particles can escape only in the positive Z-direction.*
- *motion along the axial direction is much faster than along the radial direction.*

Numerical calculations have provided much detailed insight. These have shown, for example, that a well collimi-nated narrow beam is formed, being stretched in the axial direction more than an *order* of magnitude stronger than in the radial one. Choice of characteristic parameters of the magnetic fields is also discussed.

In summary, in ref. 6, a new general mechanism for creating a well collimi-nated beam of neutral particles using magnetic fields is proposed.

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COMMENTARY

Kyoto agreement on greenhouse gas reduction and future global temperature and sea-level trends

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The global warming issue has been taken up at several intergovernmental conferences, focussing on climate changes in the 1990s. The Intergovernmental Negotiating Committee (INC) met five times before the United Nations Framework Conversion on Climate Change (UN-FCCC) was adopted in June 1992 at the Rio Earth Summit. Under this convention, it was decided that national greenhouse gases (GHG) emission inventory, as well as the strategies being adopted to deal with mitigating the induced climate changes should be reported by the governments of all signatory countries to the FCCC Secretariat. The industrialized countries (ICs) for the first time agreed to commit themselves to a legally binding schedule for the reduction of CO_2 emission. At the Conference of Parties of the UN-FCCC held at Berlin in 1995 the Berlin proclamation, also known as the 'Berlin Mandate', became the basis for future negotiations on climate changes. It placed responsibility on developed nations for setting specific targets for reduction of the GHG emissions. Although at the second Conference of Parties in 1996 the US's stand appeared positive, it soon began supporting a proposal by Germany which asked for simultaneous curbs on emissions by developing countries (DCs) like India, China and Brazil. They argued that the GHG emission from these countries is likely to be at a much higher rate in the future, and therefore this would neutralize any tangible reductions by the ICs. The European Union (EU) led the subsequent negotiations in providing a just argument for short-term targets for reduction of the GHG emission. In March 1997, the EU formally proposed that for the ICs legally binding cuts in emission of three major GHGs, namely, carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), should be set at 7.5 per cent below the 1990 levels by 2005, and at 15 per cent by 2010. On the other hand, Japan's proposal included a 5 per cent legally binding cut in GHG emission below the 1990 levels by the year 2008–2012, and further suggested flexible timetables for each country based on their economic output (gross domestic product) or population (per capita emission). Meanwhile, the G-77 and China continued to stress the underlying aspects of the Berlin Mandate such as joint implementation, emissions trading and emissions budgeting.

India brought up the issue of equitable emission rights and entitlements based on per capita emission both prior to and at the time of negotiations during the third Conference of Parties (COP 3) in Kyoto, Japan, 1–10 December 1997. Although several countries from Africa, Asia, and South America backed this proposal, USA expressed strong disagreement. Finally, an agreement was reached amongst all the delegates of the COP 3 on the last day of the meeting in Kyoto. Japan agreed to reduce its GHG emission by 6 per cent below the 1990 levels. US agreed for 7 per cent reduction, and the EU agreed for 8 per cent reduction by 2008–2012. The outcome of this agreement was achieving a net reduction target of 5.2 per cent in GHG emissions by the ICs by the year 2010. The DCs however were exempted from any commitment for reduction in their GHG emission level. During the COP 4 on UNFCCC, held in Buenos Aires, 2–14 November 1998, India and China –