cation of odour diagnostics for disease and also to examine odorant responses in the interesting gene pools in Indian populations. Uma and her group examined odour function in a sample of normal individuals as well as individuals with a variety of medical conditions. Preliminary results were sometimes at odds with those reported elsewhere. They had difficulty in applying the UPSIT tests, perhaps due to technical reasons.

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RESEARCH NEWS

Atom laser

K. G. Manohar and B. N. Jagatap

One of the significant achievements of the present decade in the area of basic sciences is the experimental demonstration of Bose–Einstein condensation (BEC) in dilute alkali vapours[1–3]. Development of very effective non-contact methods of cooling and trapping of atoms using lasers, magnetic fields, RF, etc. resulted in lowering the temperature limits steadily from millikelvin to microkelvin to nanokelvin ranges. With the achievement of BEC in rubidium atoms at a temperature of 170 nanokelvin by Anderson *et al.*[1] in 1995, a new field of physics has started which deals with coherent macroscopic matter waves. While the physics of superfluid helium does involve description in terms of coherent macroscopic matter waves, the strong interaction between the helium atoms makes the study of BEC in liquid helium rather complicated. The experimental realization of BEC in dilute alkali vapours was followed eventually by the demonstration of interference effects between Bose condensates[4], thus establishing the coherent nature of matter in BEC. The strong parallelism between conventional lasers and Bose condensates has led to the idea of atom lasers, i.e. coherent atomic beam generators[5–7]. Development of techniques for output coupling of coherent atoms from the condensates is the key to this issue and was demonstrated for the first time by Ketterle and his group[5] at MIT. Very recently, a Raman laser-based output coupling scheme has been reported by Hagley *et al.*[8], in which the output pulses from a Bose condensate have been shown to posses extremely low divergence of a few milliradians. This is comparable to the beam divergence of a typical optical laser. It is but natural that scientists have already started looking for matter wave equivalents of optical effects involving lasers. One such effect that has been demonstrated recently is the non-linear four-wave mixing of matter waves in a Bose condensate of sodium atoms[9].

Photon laser

Since the atom laser is a concept which is derived from the conventional laser, it is instructive to briefly recall some of the basic aspects of a conventional or photon laser. The main features of a photon laser are: (i) an optical gain medium, (ii) an optical cavity and (iii) a coherent photon field in the form of allowed eigen modes of the cavity. The resonator, which is formed by two or more mirrors, defines a confining volume in which the photons are trapped. The trapped photons are in a standing wave field from which a small fraction is leaked out through one of the resonator cavity mirrors which is made partially transmitting. The loss of photon field from the cavity is compensated by the gain medium which adds photons to the field in exactly the same energy, momentum and phase states, by the process of stimulated emission. Thus it is the process of stimulated emission that builds up and maintains coherence between the photons of the laser resonator cavity field. The coherence effects of the laser photon field manifest themselves in the form of a high degree of beam directionality/low beam divergence (spatial coherence) and high monochromaticity (temporal coherence). The coherence length of the laser output is much longer than the dimensions of the cavity and the coherence time is more than the cavity round trip time. The transverse intensity profile of a stable laser resonator can be described in terms of either Hermite–Gaussian functions or Leguerre–Gaussian functions. The implication of this is that the transverse confinement of the laser photons by the resonator cavity is equivalent to trapping by a two-dimensional transverse harmonic potential well. This situation resembles very closely the formation of the Bose condensate in a magnetic trap.

Bose–Einstein condensation

The achievement[1–3] of BEC itself is a big step towards the realization of atom laser. Briefly, BEC is a process by which a collection of bosonic atoms, when cooled to a sufficiently low temperature, undergo a phase transition to a state of complete atomic coherence. The achievement of BEC is preceded by a sequence of cooling by laser cooling techniques, trapping by inhomogeneous magnetic fields and the process of evaporative cooling. The inhomogeneous magnetic field provides a potential well for trapping the cold atoms. Before the onset of BEC, the collection of atoms occupies the various energy levels of the potential well with random phases. Classically this corresponds to an uncorrelated thermal motion of the atoms with randomized velocities. As the temperature is lowered by evaporative cooling, the thermal velocities of the atoms are also reduced. The atoms occupy progressively lower energy levels until at a certain critical temperature, all of them crowd into the lowest possible energy state, i.e. ground state of the trap potential. This is possible, of course, only if the atoms are bosons, i.e. particles with integral total angular momentum. Under these circumstances, the microscopic wave functions of individual atoms all add up to a macroscopic matter wave. This is a phenomenon similar to the formation of a macroscopic wavefront of light from phase correlated microscopic wavelets. Thus the collection of atoms in the trap forms a single quantum mechanical entity called the Bose condensate and is described by a single-wave function. If the trap potential is simple harmonic, then the wave function of the Bose condensate is Hermite–Gaussian or Leguerre–Gaussian modified by the interaction between the atoms. Of course, the wave function is a modified Gaussian when the condensate occupies the lowest energy state. This is a situation analogous to the transverse confinement of photons in a stable optical resonator cavity. Hence if a small fraction of the condensate can be drawn out as output, it will have a transverse intensity (matter wave intensity) profile which is similar to the normal photon laser intensity profile. The difference between the two lies in the fact that while atoms interact among themselves, there is no direct interaction between photons. It may be noted that the Laguerre–Gaussian profiles of laser light intensity represent optical beams with finite angular momenta[10] ($l \neq 0$). In the case of output from atom laser the transverse intensity profile similar to Laguerre–Gaussian corresponds to the presence of vortices in the condensate.

Atom laser

In 1997, the research group at MIT demonstrated the first rudimentary atom laser[5]. The main ingredient for atom laser is of course a source of coherent atoms, which is provided by the Bose condensate. An output coupling technique is required for extracting a small fraction of the condensate in the form of a coherent beam without disturbing the rest of the condensate. The MIT team devised such an output coupler in which, a brief burst of low intensity RF is passed through the condensate causing some of the condensate atoms to flip their magnetic substate from trapping state ($m = -1$) to non-trapping state ($m = 0$). Once this happens, the flipped atoms are no longer held by the trap, and they drop down under the action of gravity. This fraction, which drops out of the trap, is the coherent matter wave output of the device. The output of this first atom laser had a divergence, i.e. it showed lateral spreading as it dropped down. The divergence is due to the fact that as a part of the condensate becomes non-trapping, it no longer feels the confining forces of the trap and it starts expanding isotropically under the action of repulsive inter-atomic forces, while dropping down under gravity.

Recently, another output coupling scheme has been reported by Hagley *et al.*[8], which reduces the beam divergence to as low a value as a few milliradians. The technique used in this new scheme is based on two-wavelength coherent-stimulated Raman process, i.e. the role of RF in transferring atoms from trapping state to non-trapping state is replaced by a Raman transition to achieve the same effect. Figure 1 shows the arrangement employed for the output coupling technique. Two counter-propagating tunable lasers of frequencies ω_1 and ω_2, passing through the condensate of sodium atoms, are tuned near to the transition $3s_{1/2}F = 1 \rightarrow 3p_{3/2}F' = 2$ with a detuning of -2 GHz. This detuning is provided to avoid higher excitations. The two lasers with linear and mutually orthogonal polarizations

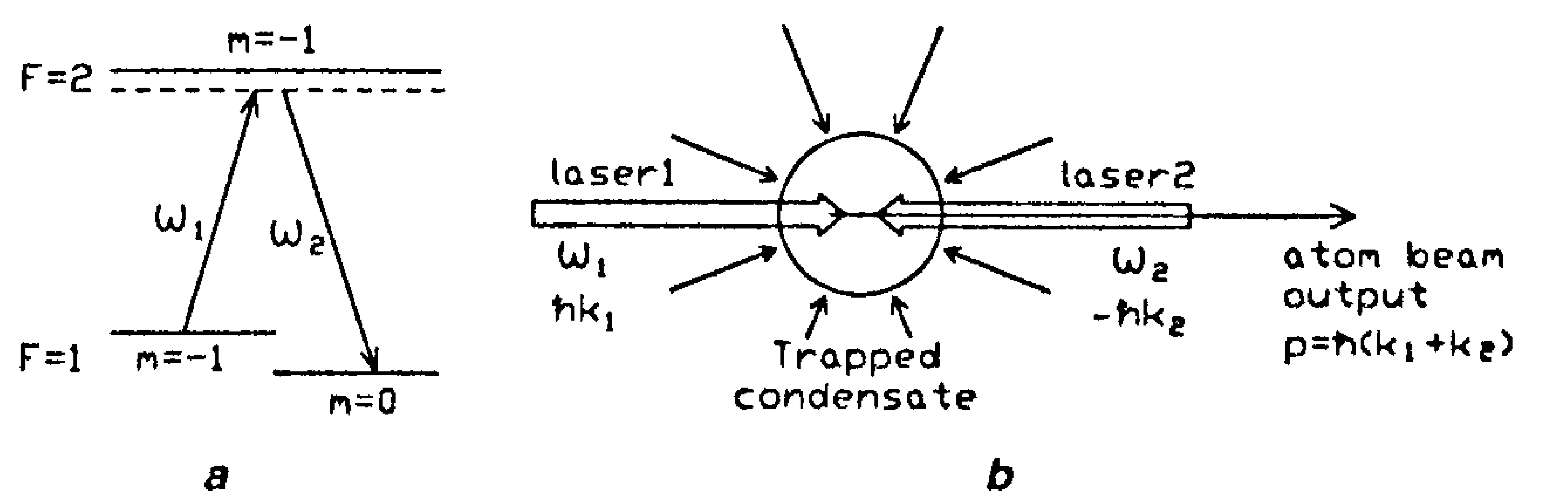

Figure 1. Schematic representation of the Raman output coupling scheme[8]. *a*, Raman transition between the trapping ($m = -1$) and nontrapping ($m = 0$) magnetic states of the hyperfine level $F = 1$. *b*, Two counterpropagating laser beams of frequency ω_1 and ω_2 coherently scatter a part of the condensate which is the output of the atom laser. The momentum p of the output can be chosen to be in any direction by appropriate orientation of lasers.

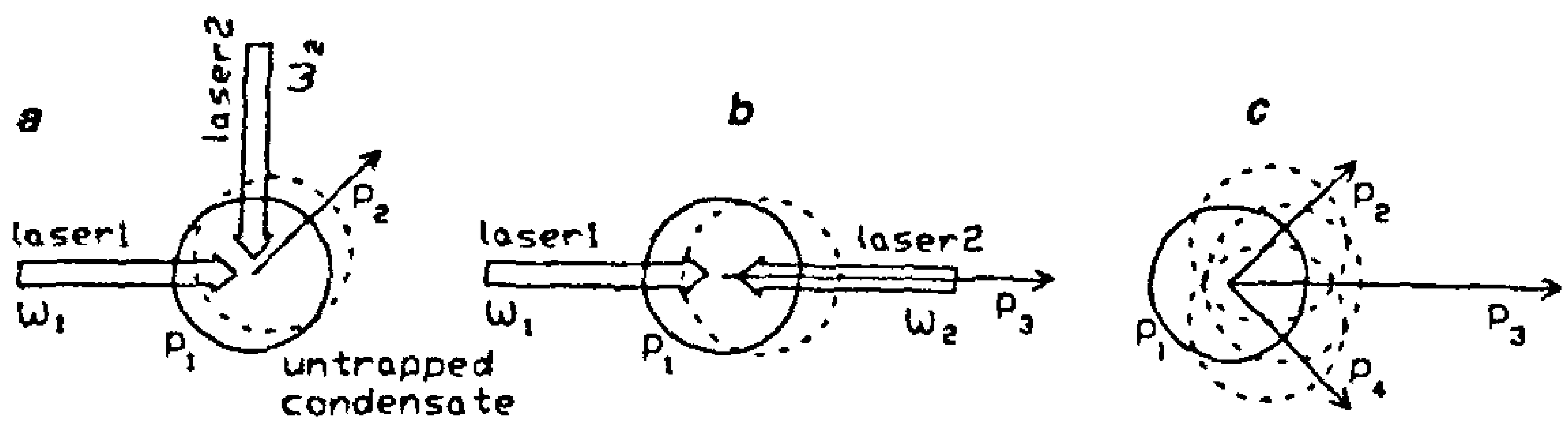

Figure 2. Schematic representation of coherent four-wave mixing of matter waves[9]. Initially the condensate is at rest ($p_1 = 0$). **a**, About one-third of the condensate aquires momentum $p_2 = (2\hbar k)^{1/2}$ along *xy* direction due to Bragg scattering. **b**, When the orientation of the lasers is changed, half of the remaining condensates move along *x*-direction with momentum $p_3 = 2\hbar k$. **c**, Condensates with momenta p_1, p_2, and p_3 interact to produce a matter wave with momentum $p_4 = (2\hbar k)^{1/2}$.

have a frequency difference which corresponds to the difference between the trapping and non-trapping magnetic states of the atoms. Thus the atoms can undergo Raman transitions from trapping state to non-trapping state by exchanging photons between the two lasers, i.e. absorption from one laser ($\hbar\omega_1$) followed by stimulated emission into the other laser ($\hbar\omega_2$). In the process of becoming free from the trap, the atoms thus acquire the momentum of two photons which is along the axis of the lasers. The released atoms leave the trap with this momentum. Since this momentum is relatively large, the atoms leave the trap quickly (in a time scale in which the repulsive forces do not cause significant spreading of the released atoms) and as a result the repulsive forces are mainly directed along the direction of motion of the atoms. Consequently, the beam divergence remains very small.

The close parallelism between atom laser and optical laser extends even into the realm of nonlinear phenomena. Recently Deng *et al.*[9] demonstrated four-wave mixing of matter waves experimentally. This is possible because the Bose condensate obeys the nonlinear Schrödinger equation (Gross–Pitaevskii equation[10])

$$i\hbar\frac{\partial\psi}{\partial t}=\left[-\frac{\hbar^2}{2M}\nabla^2+V_{\text{trap}}+NU_0\,|\psi|^2\right]\psi,$$

where V_{trap} is the trap potential and U_0 is the interatomic interaction potential. The term $NU_0|\psi|^2\psi$ in this equation is similar to the third order nonlinear term $\chi^{(3)}|E^2|E$ which is responsible for four-wave mixing of optical waves. The experimental demonstration of four-wave mixing of matter waves is as follows. A pair of lasers are arranged in two different configurations as shown in Figure 2. The laser beams are sent through the Bose condensate of sodium atoms. At the beginning of the experiment the trap holding the condensate is switched off and after about 600 μs the two lasers are pulsed for about 30 μs. During the pulse the propagation of the laser beams is along x and $-y$ directions respectively (Figure 2 *a*). This sets a part (approximately one third) of the condensate into motion by Bragg scattering along *xy* direction (45° w.r.t. *x*-axis) with a momentum $\sqrt{2}\hbar k$ for each atom where, $\hbar k$ is the photon momentum. After about 20 μs following this, the laser beam propagation directions are changed to x and $-x$ respectively (Figure 2 *b*) and the lasers are pulsed for another 30 μs. This sets another part (approximately half of the remaining) of the condensate into motion along x direction with a momentum of $2\hbar k$ for each atom. The two moving parts of the condensate interact with the remaining static part by the four-wave mixing process and generate a fourth part (Figure 2 *c*) that moves along x–y direction (– 45° w.r.t. *x*-axis). Unlike the four-wave mixing process of light waves, which requires high laser intensities, the four-wave mixing of matter waves takes place even at very low atom intensities. This is because the interaction strength NU_0 for the four-wave mixing of matter waves is quite large. In addition, while optical four-wave mixing requires a medium with nonlinear optical properties, coherent matter manifests nonlinear phenomenon without the requirement of a medium.

Finally we may mention here that the name 'atom laser' is a misnomer since laser refers to the light amplification by stimulated emission of radiation. Kleppner[6] has suggested the name 'CSAASSA' meaning coherent state atom amplification by stimulated scattering of atoms to emphasise the role of stimulated scattering in this device. Nevertheless the term 'atom laser' will continue to be used in the context of coherent atomic beam generators and their applications.

In conclusion, atom laser which started as a spin off of laser cooling and BEC research, has gone through a rapid pace of development. Already applications of the device are being discussed in the area of nano fabrication technology, gyroscopes, etc. The developments in the field of atom optics have also progressed, in the meanwhile, to such an extent that atom reflectors, atom gratings, atom lenses, etc. are a practical reality. It is possible that an integration of atom optics and coherent atom lasers is not too far in future, and such an integration is likely to drive a whole new class of research techniques and devices. For instance, a matter wave gyroscope, which is an analogue of laser gyroscope, is expected to be several times more sensitive. European space agency is already planning a matter wave-based Michelson interferometer for an extremely sensitive gravity wave detection experiment. There are still some problems to be overcome in atom lasers and their applications. The first is that unlike an optical laser, there is no gain medium which can be pumped on a CW basis. The second is that while photons can be created in a laser cavity, atoms cannot be 'created' in a trap. However, clever solutions[11] to these problems will be found eventually and atom lasers will become indispensable in research and industry as optical lasers are at present.

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OPINION

The need for removal of restriction on maps

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As is well known, a map is a representation on a flat surface to an established scale and to a definite orientation, natural physical features and also man-made features wherever present, of a part or whole of the earth's surface by accepted signs and symbols. Map-making is as ancient as some of our civilizations, and the oldest available map in the world is a Babylonian map on a clay tablet dating 2500 B.C. India has a tradition of map-making from ancient times, as gleaned from the *Brahmand Purana* of 500 B.C., giving evidence of the art of map-making. A map was always considered as a source of useful geographic information. In modern society, maps constitute the most potent source of geographical, physiographic, economic, scientific and sociological information for all development and academic activities. Topographical maps form the essential base for geological mapping, geotechnical and environmental investigations, engineering works, agricultural, botanical, forest and soil surveys, defence planning, urban and rural surveys and other activities.

Map coverage and utility

India, with an area of 3,287,263 km^2, is covered by both topographical maps and geographical maps and the Survey of India (SOI) is the principal maker of all maps in India. The topographical maps are on sufficiently large scales of 1 : 25,000, 1 : 50,000 and 1 : 250,000, enabling the individual features shown on the map to be identified on the ground by their shape and position. These maps are useful to earthscientists, geographers, foresters, engineers, archaeologists, anthropologists, scientists, planners, prospectors, miners, teachers in schools and colleges, students, researchers, tourists, trekkers, mountaineers and others. The geographical maps on the other hand, are on a small scale of less than 1 : 250,000 or 1 inch to 4 miles that strict representation of individual features for identification on the ground is not possible.

There are nearly 385 toposheets on 1 : 250,000 scale covering the mainland and the islands under the sovereignty of the Republic of India and these are also called degree toposheets. Each degree toposheet has 16 toposheets of 1 : 50,000 scale and at present the whole country is covered by 1 : 50,000 scale rigorous metric surveys in more than 5000 toposheets. This is no doubt an impressive record for any country in the world and SOI deserves all appreciation for this achievement. Each 1 : 50,000 scale sheet contains four 1 : 25,000 scale sheets. More than 35% of the country has also been covered by 1 : 25,000 scale. Therefore, there is no dearth of modern toposheets. Guide maps on scales 1 : 10,000 and smaller are available for towns and cities in various states. In India, maps particularly on scales of 1 : 250,000 and 1 : 50,000 are in great demand.

Diverse restrictions

Topographical maps, as an essential tool of information, should be available to all citizens as a matter of fundamental right. Unfortunately, the then colonial British Government in India, suspicious of its northern neighbours, introduced the principle of security of maps, which is still being pursued. The northern border skirmishes with China during the early sixties further hardened this policy. This restriction has several facets. Maps on scales larger than 1 : 1 million of areas about 80 km from the external boundaries and from coastline to onshore, including the whole of Jammu and Kashmir and the entire north-east region, and all the islands in the Arabian Sea and the Bay of Bengal, are classed 'Restricted' at the instance of the Ministry of Defence. This amounts to nearly 227 out of 385 degree toposheets being classed as restricted. The restricted toposheets are issued only to Government officials, educational and scientific institutions and semi-government organizations. However, in practice, only authorized government officials are allowed to indent for maps, and educational institutions cannot directly obtain them. Topographical maps, both for restricted as well as unrestricted areas which depict grid lines cannot be issued to civilians without the prior approval of the Ministry of Defence. Without grid lines maps lose some of their utility for easy location. Similarly aerial photographs falling within restricted or unrestricted areas are classified as secret/top-secret for the whole of India. Even the book *Gravity in India* by SOI is a restricted publication and even export of unrestricted maps is not allowed.

Many organizations in India have suffered professionally for lack of easy