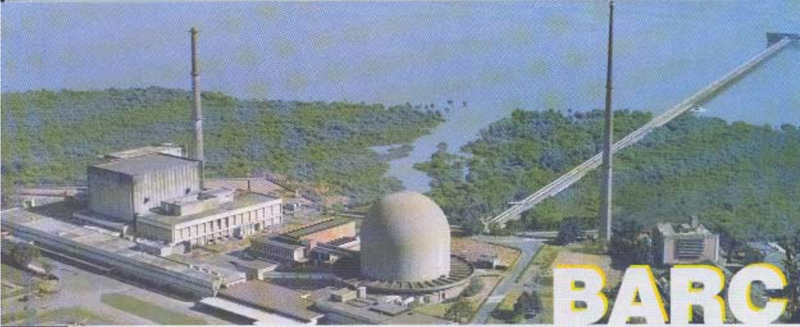

BARC
NEWSLETTER

No. 206
March
2001

Contents

LASER COOLING AT BARC

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Laser cooling refers to the techniques by which free atoms in a gas or vapour phase are cooled to extremely low temperatures using laser light. The essence of these techniques is reduction of the kinetic energy of a moving atom by the mechanical action of laser radiation at a wavelength close to the atomic resonance [1-7]. In addition to the dissipative force, the laser light in conjunction with an inhomogeneous magnetic field can exert a trapping force to localise neutral atoms in space. Laser cooling and trapping techniques thus offer a control over the external degrees of freedom of atoms, namely, the velocities and positions. The last decade or so has seen amazingly new ideas and developments in this area which include optical molasses, neutral atom traps, ultra precision measurements, time and frequency standards, collision physics of ultra cold atoms, nonlinear optics, Bose-Einstein condensation, matter wave optics and atom lasers [2-6]. These developments have made it possible to prepare dense atomic samples at temperatures down to nanokelvin range which provide an ideal testing ground for the elementary laws of physics and hold promise for several new technological applications.

India, so far, has remained isolated from all these new developments and excitements at the forefronts of physics. Laser & Plasma Technology Division and Spectroscopy Division (Atomic & Condensed Matter Physics Group) have undertaken a joint programme under the IX plan on cooling and trapping of neutral atoms. The programme is aimed at developing the precision techniques of laser cooling and trapping of neutral atoms indigenously and then go on to perform experiments at the foundations of physics using cold atoms. In this article, the developments that have happened in the programme and experimental demonstration of laser cooling of cesium atoms in BARC have been reported.

Magneto-Optical Trap

An atom placed in a laser field of wavelength λ that is tuned near the atomic resonance experiences a force due to several cycles of absorption and spontaneous emission of photons that it undergoes. Since the photon is associated with momentum $p=h/\lambda$, (h = Plank's constant), every absorption and emission process results in a change of momentum of the atom. The change due to absorption is in the direction of the propagation of laser beam and its effect is cumulative over a large number of absorption-emission cycles. The momentum change incurred due to emission, however, averages out to zero due to the isotropic nature of the spontaneous emission process. The net result is to generate a force, acting on the atom, which is referred to as "scattering force" or "spontaneous emission radiation force" [1]. By tuning the laser to the red side of the atomic absorption, this force can be made to oppose the velocity of the atoms thereby reducing its kinetic temperature. In three dimensions, atoms can be cooled by use of six laser beams along the Cartesian axes. Such a configuration is called as the optical molasses and forms the basis of the laser cooling techniques [2].

Magneto optical trap (MOT) is a device that combines the radiation pressure in optical molasses with the Zeeman splitting of atomic lines in an inhomogeneous magnetic field to achieve cooling and trapping of atoms [6]. MOT is so widely and successfully used in laboratories all over the world, that it has become a workhorse of all laser cooling and trapping experiments. Basic ideas of the working of a MOT may be understood by referring to Fig.1, which shows the simplified energy level diagram of a hypothetical two level atom placed in a 1-D inhomogeneous magnetic field. It must, however, be remembered that even the simplest atoms such as alkali atoms exhibit a very complicated Zeeman splitting pattern due to the hyperfine interaction.

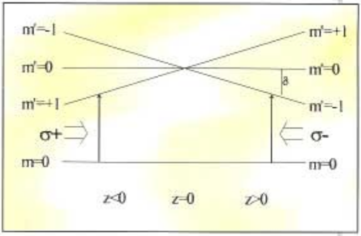

Fig.1 Basic concept underlying a magneto-optical-trap (MOT) for neutral atoms

In Fig.1, the angular momenta J of the atom in ground and excited levels are 0 and 1, respectively. The magnetic field lifts the level degeneracy and gives rise to the usual Zeeman splitting. For a field which varies linearly with distance z, the splitting is also linear i.e. $\Delta E = \mu\, m_j\, B = \mu_B\, g_j\, m_j\, A\, z$, where μ_B is Bohr magneton, g_j is the g factor and A is the coefficient of linearity. The atom is illuminated by two counter propagating laser beams of wavelength λ and of polarizations σ^+ and σ^- propagating along z an –z directions respectively. The laser is detuned from the zero field resonance towards red side by a few atomic natural line widths. As per the electric dipole selection rules, σ^+ and σ^- beams excite $\Delta m=+1$ and $\Delta m=-1$ transitions respectively. An atom, which is traveling with non-zero velocity either towards z or –z direction, will come into resonance with the red detuned laser beam, which is propagating in the opposite direction. This is due to the Doppler effect. The laser induced deceleration force from the counter-propagating beam slows down the atoms, which in effect cool down to low temperatures. Further, the presence of magnetic field makes the scattering force space dependent and directed towards the centre (z=0). Thus, laser cooling by reduction of velocities of atoms and trapping by confining the atoms near the center are achieved in the MOT. For cooling and trapping of atoms in three-dimensional space, optical molasses configuration is used along with a spherical quadrupole magnetic field.

Development of Sub-systems for Laser Cooling

Setting up of a MOT requires developments in many areas. These include UHV optical chamber compatible for laser cooling experiments, optical and opto-mechanical components, generation and mapping of magnetic field, high resolution spectroscopy, precision locking of the laser wavelength and diagnostics. In addition, the development is largely dependent on generating experience in diode lasers and handling of highly reactive alkali atoms such as cesium which are targeted for laser cooling experiments.

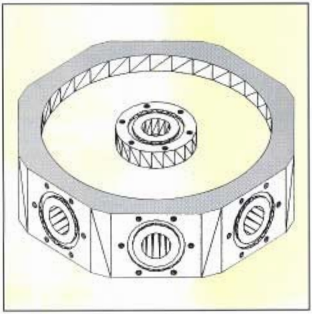

Fig.2 Stainless steel octagonal MOT vacuum chamber.

At an early stage during the development, a decision was taken to implement the programme using an all-metal MOT vacuum chamber. This was prompted by the fact that an all-glass MOT developed earlier was very fragile and broke very often. Hence, an all-metal MOT was designed and fabricated in SS. It is an octagonal vacuum chamber (see Fig. 2) with eight ports on the facets of the octagon and two ports at the top and bottom respectively. Of these, six ports along the orthogonal directions are for the entry and exit of the cooling laser beams, two ports for diagnostics of laser cooled atoms and one port each for vacuum and alkali metal reservoir. Specially designed flanges seal these ports with UHV compatible metal helicoflex seals. For the laser entry ports, the vacuum flanges are welded to GM seals which are attached to optical quality glass windows. The MOT is provided with recesses at the top and bottom for fitting spherical quadrupole magnetic coils. The inside surface of the MOT chamber is electro-polished for high vacuum compatibility. The pumping station for the MOT chamber consists of a turbo-molecular pump (150 l/sec), an ion pump (35 l/sec) and relevant vacuum gauges. The need for UHV stems from the fact that the average lifetime of the trapped atoms in the MOT is governed by the collisions with the background gas. The system was conditioned to obtain vacuum in the range of 10^{-9} torr on day-to-day basis. A specially designed Cs reservoir is attached to the MOT chamber, which ensures a controlled transfer of Cs vapour into the chamber.

Spherical quadrupole magnetic field is realised by placing on the MOT two identical coils separated by a specified distance and carrying opposing current ("anti Helmholtz" configuration). The coils used in our experiments have inner diameter of 60 mm and are formed using 60 turns of enameled copper wire of 2.3 mm diameter. These design considerations are backed by extensive simulations and mapping of the magnetic fields. Two such coils fitted onto the MOT chamber (top and bottom recesses) ensure a magnetic field gradient of 10 G/cm or more over a region of ~ 1cm, which essentially forms the trapping region in the MOT. A low voltage, high current regulated DC power supply is used for supplying current to these coils.

The laser cooling equipment, which consists of the MOT chamber, optics and opto-mechanical components, is set up on an indigenously built vibration isolated optical table having a cutoff

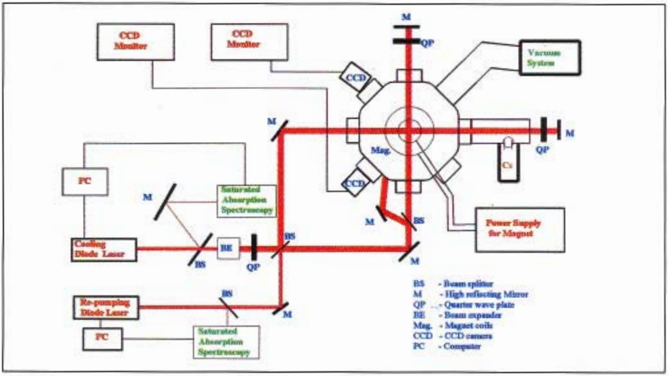

Fig.3 A schematic diagram of optical layout for the MOT.

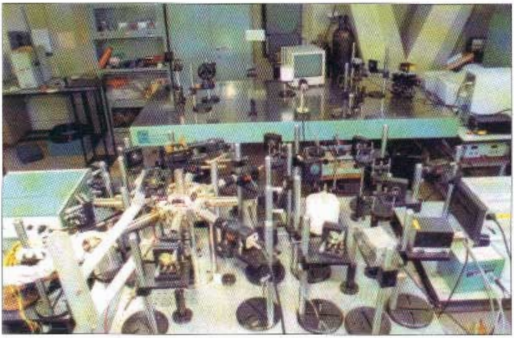

Fig.4 A view of the MOT assembly.

frequency of ~ 2 Hz and amplitude less than 10mμ. The optical configuration of the experiment is shown in Fig. 3. This includes the diode lasers, setup for saturated absorption spectroscopy of cesium, laser beam expansion and polarization optics, beam splitting, three-axis cooling beam arrangement and provision for hyperfine re-pumping. The Doppler-free saturated absorption spectroscopy (SAS) setup is required for precise tuning and locking of the laser beams on or near the atomic transition. About 10% of the laser output is used for SAS while the remaining 90% is sent to the MOT chamber for cooling of atoms. The whole set up was realised in practice by careful planning and by due consideration to the actual dimensions of the optics and opto-mechanical components to be used. The optical and opto-mechanical components were designed and fabricated to our specifications. Fig. 4 shows a view of the complete optical and opto-mechanical assembly including the MOT on the vibration-isolated table. It must be mentioned here that this critical optical alignment is made difficult by the fact that the output of the diode laser at 852nm wavelength is invisible and CCD cameras have to be used to see the beams and carry out alignment.

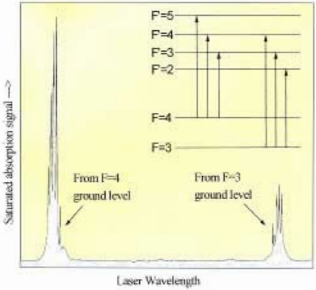

Fig.5 Saturated absorption spectrum obtained for the D_2 line of atomic Cs, which shows each of the hyper-fine transitions and cross-over resonances clearly resolved. The inset shows the relevant energy level diagram.

The source of laser radiation for laser cooling is a tunable external cavity diode laser in Littrow configuration. The laser can be tuned by applying a voltage to the PZT that changes the angle of a grating in the laser cavity. A computer control for the laser tuning through a data acquisition and control card (Dynalog PCL812), which also serves the functions of digitizing analog output from the photodiode that detects SAS signals, was set up. Thus, under software computer control, it is possible to scan the laser and acquire SA-spectrum of cesium atoms. Fig. 5 shows the SA-spectrum of cesium D_2 atomic transition obtained by us in which all the hyperfine components are clearly resolved.

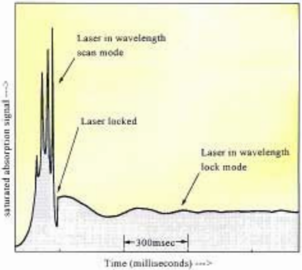

Fig.6 Locking of diode laser wavelength on the hyperfine transitions of Cs. The laser is scanned to identify the F=4 → F'=5 hyperfine transition and locked to the shoulder of the line using the saturated absorption signal.

Such high-resolution spectra enable us to lock the diode laser to the shoulder of any of the hyperfine peaks either by software control or by a dedicated electronic locking system. The later system has been designed and fabricated in our lab. Software locking has the advantage of achieving laser locking without additional hardware, while the electronic locking achieves a tighter and more accurate locking. Fig.6 shows the laser locking on the 6sF=4 → 6pF=5 hyperfine transition of Cs.

Laser cooling of alkali atoms is complicated by the hyperfine structure. Particularly in Cs, while the cooling laser beam addresses the transition 6sF=4 → 6pF=5, non-resonant spontaneous Raman transition populates 6sF=3 level eventually. Since this level is not optically coupled to the cooling transition, laser-cooling process comes to a halt in due course. To avoid such a population trapping in 6sF=3 level, a second (re-pumping) laser is installed and tuned to the transition 6sF=3 → 6pF=4. The setup for this laser includes optics and opto-mechanical components for SAS of cesium for locking the laser to the re-pumping atomic transition. The scheme of control for the re-pumping laser is similar to that of the main cooling laser to a large extent.

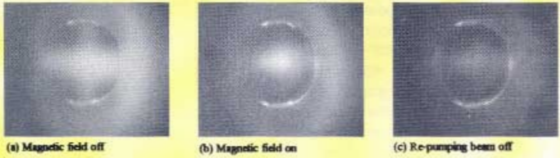

Fig.7 Fluorescence imaging of Cs atomic cloud in the MOT vacuum chamber. (a) Quadrupole magnetic field off. (b) Magnetic field on, which collapses the fluorescence into a compact ball. (c) Magnetic field on but re-pumping laser beam off, showing the importance of re-pumping.

Laser Cooling Experiments

After testing and integrating all the subsystems of the MOT, experiments were undertaken to cool and trap cesium atoms in micro Kelvin temperature range. The idea behind these experiments is to demonstrate laser cooling and further optimise the performance of the MOT. These experiments enable us to gather an invaluable experience of "handling" cold atoms, which is very important to our planned work.

In these experiments, the trapped cloud of cold cesium atoms was observed by the fluorescence they emit in the MOT. CCD cameras are used for imaging the fluorescence of the atomic cloud. The sequence of steps involved for obtaining laser cooling is as follows. The diode laser, used for cooling, is scanned and SAS of D_2 line of cesium is obtained. Using this spectrum, as a reference, the laser is locked to the shoulder of the hyperfine transition $F=4 \rightarrow F=5$ by either hardware locking or software (program control) locking. The detuning of laser wavelength from the atomic resonance wavelength is 60MHz (0.002cm^{-1}) on red side. The re-pumping diode laser is also scanned and saturated absorption spectrum obtained to identify and tune the laser to the hyperfine transition $F=3 \rightarrow F=4$. The optical arrangement (see Fig. 3) ensures that cooling and repumping lasers of correct polarisations and dimensions enter the MOT chamber and intersect at the centre of the chamber.

The cesium reservoir is opened to the MOT chamber through a high vacuum compatible valve. The cooling laser beams, passing through the MOT chamber in the three-axis geometry, excite the cesium atoms in the vapor resulting in a bright fluorescence of the Cs vapor. The diagnostics ports on the MOT chamber are used for viewing and imaging this fluorescence. In the absence of the magnetic field, the atoms are uniformly distributed in the chamber volume and the fluorescence is diffusely spread through out the path of the laser beams. Fig.7a shows the image of cesium fluorescence in the MOT without the magnetic field.

A current of 30A is passed through the magnetic coils of the MOT chamber to excite the spherical quadrupole magnetic field. The combined action of the magnetic field and the laser field exerts a dissipative and confining force to cool and trap the atoms at the center of the MOT. The effect of this confinement can be seen in Fig.7b, which shows the image of the fluorescence emanating from a smaller volume exactly at the center of the trap. When the magnetic field is switched on, the fluorescence pattern shown in Fig.7a collapses into the pattern shown in Fig.7b. This is a clear demonstration of cesium atoms being trapped at the center of the MOT. The depth of the trap is quite small which indicates that the trapped atoms are at a low temperature.

The importance of re-pumping laser is evident from Fig.7c, which shows a very weak fluorescence in the MOT with the magnetic field on, but with re-pumping laser blocked off. The weak fluorescence is due to the fact that in the absence of the hyperfine pumping provided by the re-pumping laser, the atoms get trapped in the ground F=3 hyperfine level and are lost from the MOT since they are no longer confined.

Challenges Ahead

The laser-cooling programme in BARC is organised in three distinct phases; the first one being the experimental demonstration phase. A successful completion of this phase is very important to the programme since this includes the development of infra structure, special techniques and capabilities for next phases of the programme; namely, the ultra precision spectroscopy and Bose-Einstein condensation. In that sense, the present work is an important step towards much broader and higher objectives.

The immediate task after achieving laser cooling is to start work on detailed diagnostics of the cold atoms, which include measurements of temperature and atomic density. As is well known, very specialised techniques are required for measurements of temperatures in micro and sub-microkelvin range. The efforts now will also be on achieving and characterising colder and denser atomic clouds in our system. The thrust forward shall involve developments related to two major issues, namely, the atom traps for tighter and lossless confinement and techniques to cross the "recoil limit" of the atomic cooling process [3,7].

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WATER CHANNEL FOR SUPERSONIC FLOW INVESTIGATIONS

In order to study the behaviour of bodies immersed in a supersonic gas stream in respect of shock wave patterns, wake patterns, etc., a water channel has been designed and set up at Chemical Engineering Laboratory V, Prototype Development Section (PDS), Chemical Engineering & Technology Group, BARC.

Basic Concepts

There exists an analogy between two dimensional gas flow and shallow free surface waterflow (with negligible vertical acceleration). The mathematical equations governing these two flows are of the same nature if the water were replaced by a fictitious " hydraulic gas" with a ratio of specific heats $\gamma = 2$.

Analogy relations are as follows :

Two Dimensional Gas flow	Water flow (Hydraulic Gas)
Density ratio, ρ/ρ_0	Water depth ratio, D/D_0
Temperature ratio, T/T_0	Water depth ratio, D/D_0
Pressure ratio, P/P_0	(Water depth ratio)^2 , $(D/D_0)^2$
Velocity of sound, $a = (\gamma P/\rho)^{0.5}$	Wave velocity, $c = (gD)^{0.5}$
Mach No., $M = V/a$	Froude Number, $Fr = V/c$
Subsonic flow, $M<1$	Streaming water, $Fr<1$(subcritical)
Sonic flow, $M=1$	Critical flow, ($Fr = 1$)
Supersonic flow, $M > 1$	Shooting Water, ($Fr > 1$) (supercritical)

Froude and Mach Numbers

In water, the velocity of propagation of long gravity waves, c, is given by $(g D)^{0.5}$ when depth D is small compared to wave length. This velocity is analogous to velocity of sound wave. Signals are carried by long gravity waves on the surface of an open channel where gravity is the restoring force in very much the same way as sound waves where elasticity is the restoring force. Surface tension waves, which are also present, do not, however, play any role in the analogy.

Shock Waves and Hydraulic Jumps

In the flow of gas or water, it is possible for a discontinuity to exist. While in gas, such phenomenon is a shock wave which causes an abrupt rise in pressure, density and temperature of the gas, and a decrease in velocity, in case of water, such a discontinuity manifests itself by sudden rise in depth which is termed as Hydraulic Jump (this is accompanied by reduction in velocity). As shock waves occur in case of gas flow with $M>1$, hydraulic jumps occur in case of open channel flow of $Fr > 1$. It is possible to use hydraulic jumps to simulate qualitatively most of the features of gas flow with shock waves such as flow in a De- Laval Nozzle, flow past a supersonic aerofoil, flow in supersonic inlets of various types, etc. It could provide a very effective means to study and compare shock patterns in various types of intake and study other effects like shock dynamics, such as shock oscillations, i.e. buzz in intakes, etc. The most valuable aspect of the water channel undoubtedly lies in the ease with which these phenomena may be demonstrated visually.

Another aspect is that, in many cases, it is not justifiable to go for a wind Tunnel facility due to the huge cost and space requirement. Water channel provides a very good alternative in terms of cost, size, ease of fabrication, operational flexibility for experimentation and ease of photography (complicated and expensive Schlieren system is not required).

Description of the Setup

The water channel has been designed for a Froude number of 4.0, which is analogous to a Mach number of 4.0. The system essentially consists of a 2-Dimensional De- Laval Nozzle, which receives water from a reservoir at subcritical condition, accelerates the free surface flow to a supercritical condition of $Fr = 4.0$ through a critical throat, and discharges into a sump where from water is pumped back to the reservoir. The test section is downstream of the throat and models are kept by means of proper fixtures. Adjustable dam creates back pressure. The entire work, including system design, model design, and fabrication and commissioning, has been undertaken by a team at PDS. In the absence of any ready to use design

Fig.1 Water channel (looking downstream)

Fig. 2 Water channel with fixtures for experiments

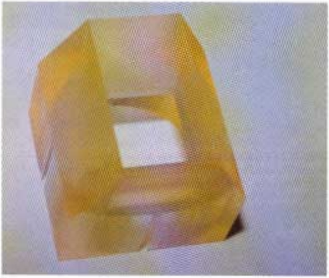


Fig. 3 Large scale rapid prototype model of an internal compression inlet designed using results obtained from water channel experiments

guidelines, the challenge involved in the design of such system lies in drawing concepts from two different fields, i.e. Hydraulics and Aerodynamics, and successfully blending them to cast into a suitable design technique. This water channel is presently operational and has proved to be a very potent tool for supersonic flow investigations.

Since qualitative agreement between the phenomena is good, the water channel is an excellent piece of demonstration apparatus as the photographs indicate. It is of value, therefore, for indicating shock wave pattern to be expected in any new system; for example, oblique shock entries for supersonic diffusers.

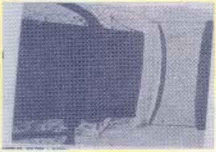
There remain, however, some serious limitations in that the method gives an indication about two dimensional flow only, and the boundary layer effects in the gas may differ significantly from those in water.

Further work is contemplated with this water channel to simulate more complicated gas flow conditions than the linear one.

Water channel photographs of Shock pattern

Typical wind tunnel Schlieren photographs of shock patterns

FLOW DIRECTION ←



SIMPLE SUPERSONIC INLET (PITO INTAKE)

Flow decelerates through detached bow shock wave at the leading edge. High spillage leads to poor intake performance. Large irreversible energy loss. Poor intake performance particularly against high back pressure

←

SUPERSONIC FLOW PAST A DIMOND SHAPE BODY IN FREE STREAM SUPERSONIC FLOW

Photograph shows leading edge oblique shock, expansion wave, tail shock and wake.

←

EXTERNAL COMPRESSION SUPERSONIC INLET (CENTRE BODY)

Oblique shock generating body placed in Pito Intake improves performance Flow decelerates through oblique shock system grazing past the cowl lip. Low irreversible energy loss. No spillage

Good intake performance against high back pressure

←

INTERNAL COMPRESSION SUPERSONIC INLET **OBLIQUE SHOCK INTERSECTION**

Flow decelerates through intersecting oblique shocks generated by wedges. Low irreversible energy loss. No spillage

Normal shock swallowed at the intersection. Good intake performance against high back pressure

A LOW COST DIGITAL POCKET DOSEMETER BASED ON Si DIODE DETECTOR

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Radiation Safety Systems Division

Introduction

Personnel monitoring is usually carried out using passive dosemeters like photographic film or thermoluminescent dosimeters owing to their recognition as legal dosimeters, low cost, and small size. However, there is a considerable delay in getting the results from the passive dosimeters as they are evaluated once in 4 weeks or more. Therefore, for day–to-day dose control, these passive dosimeters are being supplemented by ion chamber based quartz-fibre pocket dosemeters or electronic digital dosemeters for daily dose updates in potentially high dose rate areas. The electronic dosemeters usually incorporate either a miniature GM counter or a solid state semiconductor detector, and are designed to measure deep dose equivalent for photons in the range of 50 KeV to 1.3 MeV. The integrated dose is digitally displayed in these dosemeters. In some of the dosemeters, visual / oral alarm is also produced when the radiation dose received exceeds a preset value. These dosemeters have a number of advantages over passive dosemeters such as better potential for greater accuracy, lower detection limits and a high level of acceptance among workers. They are also preferable to quartz-fibre dosemeters as they have better resolution, much wider dynamic range, less susceptibility to humidity and mechanical shock and unambiguous digital readout. Some of the locally available digital pocket dosemeters are based on GM detectors and they suffer from disadvantages such as need for a high voltage for operation of the detector, high energy dependence, high power consumption, large in size and weight, etc. A compact digital pocket dosemeter, "DIGIDOSE", based on a Si diode radiation detector, has been developed in BARC. The dosemeter is comparable in size and performance to any such pocket dosemeters in the world and is much lower in cost.

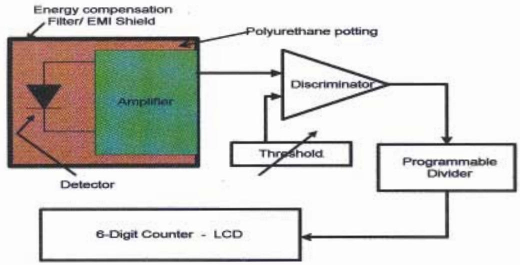

Fig. 1 Bock diagram of digital pocket dosemeter

Description

The block diagram of the pocket dosemeter is shown in Fig.1. The detector is a low cost commercially available Silicon (Si) rectifier diode operating at a low reverse bias of about 4V. A charge-sensitive amplifier based on a low power CMOS IC amplifies the pulses from the detector due to the incidence of ionising radiation. The amplifier has a sensitivity of 250 mV / MeV. The part of the circuit consisting of the detector and the amplifier is provided with an energy compensation filter, which doubles as electromagnetic shielding and is potted with an anti-vibration polyurethane compound.

The pulses from the amplifier are fed to a discriminator with a threshold voltage adjusted to cut off the noise pulses. The detection threshold of the detector-amplifier circuit is 40 KeV. The pulses at the output of the discriminator are fed to a programmable divider circuit for calibrating the dosemeter so that one count corresponds to 1μSv (^{137}Cs gamma). After division the counts are accumulated in a 6-digit-counter-LCD-display module. The dosemeter covers a range of 1μSv to 999999 μSv. Battery low indication / warning is provided through a blinking LED (Light Emitting Diode). The LED blinks when battery voltage is low. The blinking frequency indicates the Battery State. Blinking starts at a low frequency of one flash per 3-4 seconds, when approximately 8 hours of battery life is still available. The blinking LED method of battery low indication, apart from indicating the state of the battery through the rate of flashing, results in a significant reduction in the current drain from the battery during the initial warning phase of the indication.

Energy response

The energy response of the pocket dosemeter is shown in Fig.2. The energy response is within ±25% from 60 KeV to 1.25 MeV.

Dose rate characteristic

The dose rate characteristic of the instrument response is shown in Fig.3. The response is linear within ±10% up to 0.5 Sv/h and within ±20% up to 5 Sv/h.

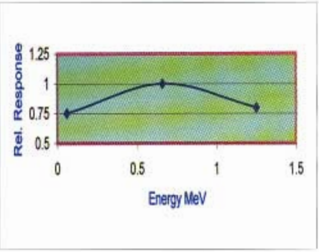

Fig. 2 Energy response

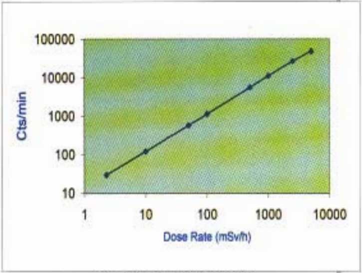

Fig. 3 Dose rate characteristic

Angular response

The Angular response of the dosemeter is shown in Fig.4. The directional dependence is within ± 20% for a variation of angle of incident radiation from –90° to +90°.

Reproducibility of response

Twenty five dosemeters, randomly selected from a production lot of 100 dosemeters, were tested for reproducibility of response. Fig.5 shows the distribution of the reproducibility of these dosemeters. It can be seen that the reproducibility is better than ±2%.

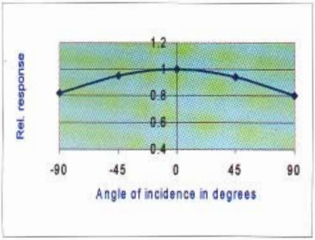

Fig. 4 Angular response

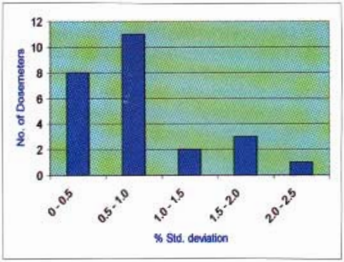

Fig. 5 Reproducibility of response

Conclusion

Fig.6 shows the photograph of the dosemeter. A single printed circuit board of thickness 0.8mm, width 25mm and length 80mm contains the entire electronic circuitry consisting of surface mount components. The dosemeter works on 6V (two coin type Li cells, type CR2320) and the power consumption is less than 2mW when subjected to a radiation field of 0.1 mSv/h. The size of the instrument is 110mm L X 30mm W X 14mm H excluding Clip and it weighs about 60 gm. Battery life is over 400 hours of continuous operation. A lot of 2500 rectifier diodes being used in the dosemeter were procured to check the sensitivity variation. 300 diodes were randomly selected and their sensitivities were checked. The spread in sensitivity was within ± 20%. More than 300 dosemeters of this type have been fabricated using these diodes as detectors and are undergoing user trials.

A new switch-less model of the "DIGIDOSE" has also been developed to cater to the requirements in power plants where the dosemeter is to be safeguarded against inadvertent or deliberate switching off by workers. These dosemeters are normally on and they are switched off only when they are stored in a specially designed storage rack. A normally closed magnetic reed switch is used

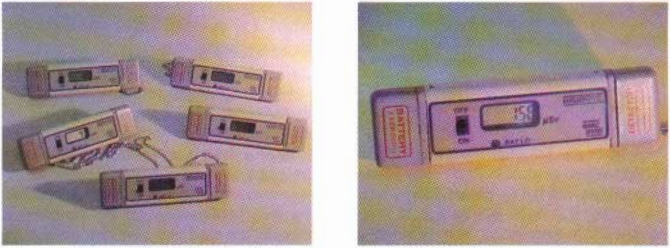

Fig. 6 Photographs of the digital pocket dosemeter

in place of the on-off switch of the instrument. The switch opens only when the reed switch is subjected to a high magnetic field, which is normally not encountered in the working areas of the power plants. A storage rack for housing six dosemeters has been fabricated with permanent magnets implanted in proper locations to switch the units off when stored in the rack. Another version of the dosemeter, "Dosealert", has been developed to meet the requirement for a direct reading dosemeter with a preset alarm facility to warn personnel when the radiation received exceeds a preset level. This new version has selectable integrated dose alarm levels of 256, 512, 1024 and 2048 µSv. The unit gives audible alarm when the accumulated radiation dose exceeds the preset value.

The manufacturing cost of "DIGIDOSE" is less than Rs 1,500. Large-scale manufacture of these pocket dosemeters will help meeting the increasing need for active dosemeters in the nuclear industry.

SEMINAR ON 'FIRE AUDIT AND FIRE HAZARD ANALYSIS'

A seminar on 'Fire Audit and Fire Hazard Analysis' sponsored by Board of Radiation in Nuclear Sciences (BRNS), was organized on December 21, 2000 at the Multipurpose Hall, BARC Training School Hostel, Anushaktinagar, Mumbai. About 160 delegates comprising representatives of Mutual Aid Scheme and Safety Coordinators from BARC/NPC/AERB participated in the deliberations.

Recently, Dr Anil Kakodkar, Director, BARC, had opined that there was need for Fire Services Section to update Fire Audit and Fire Hazard Analysis for all the installations in BARC with the help of safety coordinators. In this context, the seminar was a timely one, specially for the safety coordinators to get themselves acquainted in the field of analysis.

BARC is the founder member of Mutual Aid Scheme. The aim of the scheme is to assist each other in grave fire emergency and disasters. Presently, it enjoys the membership of representatives from public and private sectors totalling twenty-three industries located in the Chembur-Trombay Industrial Zone.

The Convenor of the seminar, Mr S.K. Ghosh, Head, Chemical Engineering Division, BARC, welcomed the delegates, and, in his introductory speech, traced the history of Mutual Aid Scheme spanning thirty years. He stressed the importance of this scheme in light of the existing chemical, petrochemical, fertilizers, thermal and nuclear facilities in the Trombay-Chembur area which made it a highly sensitive industrial zone.

Mr B. Bhattacharjee, Director, Chemical Engineering & Technology Group, BARC, delivering the inaugural address. On the dias, from left are Mr P.K. Ghai, GM(TO), RCF, Mr D.S.C. Purushotham, Director, Nuclear Fuels Group and Chief Guest of the seminar, Mr S.K. Ghosh, Head, Chemical Engineering Division & Convenor, and Mr A.K. Tandle, CFO

Mr B. Bhattacharjee, Director, Chemical Engineering & Technology Group, BARC, while inaugurating the seminar, spoke on continued support of BARC to the Mutual Aid Scheme and appreciated its role. He expressed his confidence in the ability of the members of MAS to handle all cases pertaining to fire protection and fire fighting. Referring to the recent advances made in this field, he mentioned the need for developing/procuring the codes (if available) that could predict the consequences of a fire accident and also the measures to be taken to prevent it. In addition, he emphasized the introduction of environmental friendly fire extinguishers.

Mr D.S.C. Purushotham, Director, Nuclear Fuels Group, BARC, who was the Chief Guest at the seminar, recalled the Chernobyl incident and the damage caused by the fire. The subsequent thorough review carried out, he added, has led to a number of implementations in nuclear installations. He also mentioned about the adequate precautions that are to be taken in the storage of combustible pyrophoric metals.

During the demonstration of safe procedures, (left to right) facing the camera are Mr S.K. Ghosh, Mr D.S.C. Purushotham, Mr B. Bhattacharjee and Mr A.K. Tandle

Mr P.K. Ghai, General Manager (Trombay Operations), RCF, referred to MAS as a mass group with a good track record. While appreciating the need for quick response to reach the site of emergency, he cautioned against complacency and emphasized the need to learn lessons from incidents and to familiarize with processes so that a real emergency can be efficiently handled.

The seminar was spaced in two technical sessions with seven invited talks. The first technical session was chaired by Mr H.S. Kushwaha, Head, Reactor Safety Division, BARC. In this session, Mr P.K. Ghosh of AERB talked on "Fire Hazard Analysis of Chemical Plants", covering vital aspects to minimize fire hazards and fire prevention strategies. Mr M.G. Joseph, ISG, NPCIL, dealt with various methodology from Fire Audit, including compositon of audit teams, check list, field visit, documental review, reports, etc. Mr S.G. Markendya, RSD, BARC, explained "Analytical Methods of Modeling Fire in Nuclear Power Plants (NPPs)", and reviewed certain aspects to ensure safety of NPPs in the event of a fire. It included analytical simulations of fire propagation and the damage assessment with the help of computer code. Mr A.K. Babar, BARC, spoke on "Fire Hazard and Risk Analysis of NPPs" and discussed the identification of fire hazard as a major contribution to a plant operational risk and classification of fire at different locations of plant.

The second technical session was chaired by Mr M. Das, Associate Director, HSG, NPCIL. In this session, "Human Behaviour & Safety" was discussed by Dr R.K. Kapoor. The talk covered the topic of introducing a system of studying and analysing behavioural aspects of human error and how to correct unsafe behaviour of humans by an approach known as "Behaviour Based Safety Management". Dr M.C. Abani, Head, Radiation Safety Systems Division, BARC, dealt with classification of biological effects of radiation and presented statistics of recommended dose limits from man--made sources of radiation.

Finally, Mr A.K. Tandle, Chief Fire Officer, Fire Service Section, BARC, summarized the various R&D facilities installed in BARC and the approach to Fire Safety adopted by Fire Services Section while dealing with research reactors, reprocessing plants, fabrication plants, radiological/chemical laboratories, etc. His talk described different Fire Appliances and Fire Fighting Operations in radiation environment and also the co-ordination work with Mutual Aid Scheme Members in the Chembur-Trombay Industrial Zone.

Mock exercise conducted by Mutual Aid Scheme members

In its endeavor to be fully prepared for any eventuality, a mock exercise was organized by BARC with emphasis on checking the response time of Fire/Rescue Tenders. The mock situation on December 12, 2000 involved two vehicles having caught fire after a collision and the trapping of persons inside the vehicles at South Gate, BARC,

Rescue crew members of Mutual Aid Scheme pose for a group photograph with fire appliances in the background

near Tata Electric Company. The action call was sounded at 11.50 hrs from the Control room of BARC Fire Services Section, whereby all Mutual Aid Members were telephonically informed about the incident. The call was responded by Fire Tenders and crew with an average response time of eight minutes from nine members, viz. RCF, AEGIS, MbPT, BPCL, TEC, APAR, CTTL and HPCL in addition to BARC Fire Tenders. As a stand by, the Naval Armament Depot and Mumbai Fire Brigade units at Chembur and Deonar were alerted.

The outcome of the drill was a fulfillment of its objective - ASSURED RELIABILITY and COORDINATION. The average response time of eight minutes was appreciated and so was the coordination - the backbone of fire fighting in any emergency.

BARC SCIENTIST HONOURED

- Dr Goutam Dev Mukherjee of High Pressure Physics Division, BARC, was selected to participate in the Young Physicists Colloquium 2000 organised by Indian Physical Society, held at Saha Institute of Nuclear Physics on August 24 and 25, 2000. He was awarded the third best prize for his paper entitled, "Thermal expansion: an effective approach for the determination of vibrational contribution in solids". The award carried a citation, some books and a cash prize of Rs 1000.

- Mr V.M. Joshi, Head, Ultrasonic Instrumentation Section of Electronics Division, BARC, has been awarded "Non-Destructive Evaluation Achievement Award" for his contribution to Research & Development in Non-Destructive Evaluation by the Mumbai Chapter of Indian Society for Non-Destructive Testing. The award was given to Mr Joshi on September 23, 2000. Mr Joshi has been actively involved in the development of an Ultrasonic Imaging System (ULTIMA 100+) suitable for ultrasonic testing/inspection of materials (NDT/NDE) and the award has been given in recognition of this indigenous development.

- Mr R.K. Modi, Head, Special Systems Development Section, Division of Remote Handling and Robotics, BARC, has been awarded the National NDT award - 2000 for 'System Innovation & Development'. He has developed a number of remotised NDE systems, including Periscope of FBTR, 20-metre long Manipulator for visual examination and ultrasonic testing of TAPS core shroud, and Eddy current testing system for NAPS moderator heat exchangers. He is presently working on the development of systems for remotised underwater testing of MOX fuel and 12-metre long corescope for PFBR.

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Editorial Management : T.C. Balan; Computer graphics & layout : P.A.S. Warriyar.

BARC Newsletter is also available at URL:http://www.barc.ernet.in *(for private circulation only)*