CSIR - NPL

TIME AND FREQUENCY DIVISION

Our division is responsible for the highest level of time and frequency measurements in India and keeping them traceable to the the International Bureau of Weights and Measures (BIPM) using ultraprecise satellite links. In simple words, we maintain the **Indian Standard Time** (IST). The time keeping by us is based on a bank of Cesium (Cs) atomic clocks and a Hydrogen maser. *These clocks are so accurate that they would lose or gain one second in about three lakh years*. The traceability of our time scale with BIPM is at the level of few nano-seconds (ns). In addition, we carry out research and development on primary atomic clocks. Our first Cs fountain clock, with an accuracy of a few parts in 10^{-15}, became operational in 2011. A second Cs Fountain is under development (project **NOVOCEF**). Recently, we have started developing a more accurate clock ($\approx 10^{-17}$) at optical wavelengths based on a single trapped Ytterbium ion (project **STIOS**).

Indian Standard Time:

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CSIR - NPL

TIME AND FREQUENCY DIVISION

Research Activities :

- **Precise Timing Systems**
  - *Maintenance of Indian Standard Time*
  - *Dissemination of Time*
  - *Calibration and Testing*
- **Microwave Frequency Standards**
  - *Cesium Fountain I and Cesium Fountain II*
  - *Rubidium Atomic Clock for Space*
- **Optical Frequency Standard**
  - *Single Trapped Ion Optical Standard (STIOS)*

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TIME AND FREQUENCY DIVISION

Precise Timing Systems

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Time scale at CSIR-NPL

Precise Timing Systems

CSIR-NPL Stands as TIME KEEPER of the COUNTRY

CSIR-NPL is the responsible for highest level of time and frequency measurements in India and keeping it traceable to the international standards. Time is one of the three primary units of physical measurement that has been maintained at NPL since its inception Since 1974, the time keeping has been based on one or more Cesium (Cs) atomic clocks.

The major activities in timekeeping at NPL comprise the following:

- Maintaining the group of several Cs atomic clocks with stringent environment control and clean uninterrupted power.
- Establishing a precise time transfer link (or traceability) between this time and the international time at International Bureau of Weights and Measures (BIPM), Paris using a continuous satellite link.
- Disseminating the precise time and frequency to users within the country via teleclock and NTP server.
- We undertake calibration of various frequency standards, clocks and timers.

CSIR - NPL

TIME AND FREQUENCY DIVISION

Microwave Frequency Standards

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Cesium fountain frequency standard at CSIR-NPL

Cesium fountain frequency standards

Cesium fountain clocks provide most precise and accurate measurements of time and frequency. Most of the developed countries have developed such clocks which are already operating as primary standards. CSIR- National Physical Laboratory India (NPLI) started efforts to realize India's first fountain clock only few years back. The first cesium atomic fountain (India-CsF1) frequency standard is now completely assembled and operational. The CsF1 fountain has a (0, 0, 1) geometry of the magneto-optical trap (MOT) for cooling and launching operations. In this geometry, four out of the six cooling beams are in horizontal plane and other are going up and down, respectively. The atoms are first loaded and cooled in MOT followed by further cooling in optical molasses (OM). They are launched using moving molasses (frequency detuning of vertical beams) and cooled further with polarization gradient cooling. The operational parameters are currently being optimized and the complete frequency evaluation will soon be done.

The division has recently started a project to design and build a second Cs fountain (NOVOCEF) with special design features that enable us to carefully investigate the systematic errors in order to enhance the accuracy of our frequency standard to a few parts in 10^{16} – which would be at the level of the best in the world. One special feature of the design would be to employ a novel method of optical pumping using two lasers to enhance the number of cold atoms taking part in the microwave interrogation process. It is also planned to use an elaborate design of the microwave cavity in order to reduce "distributed microwave cavity phase shift".

CSIR - NPL

TIME AND FREQUENCY DIVISION

Microwave Frequency Standards

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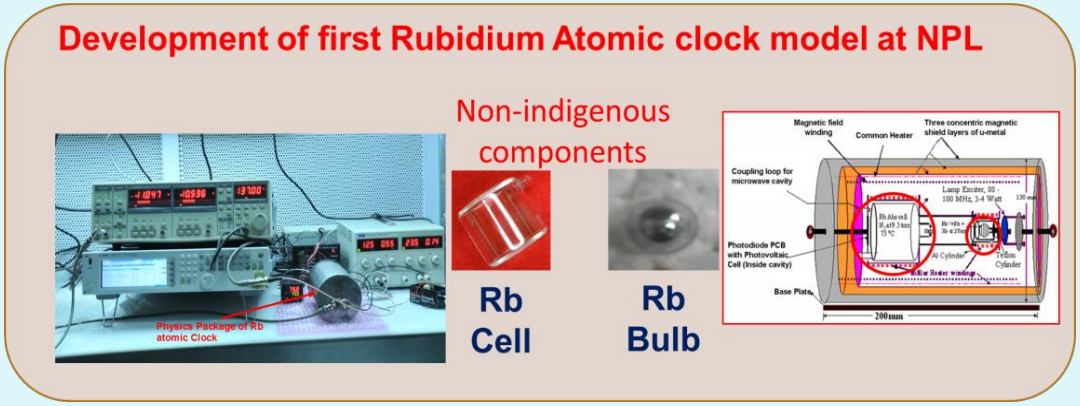
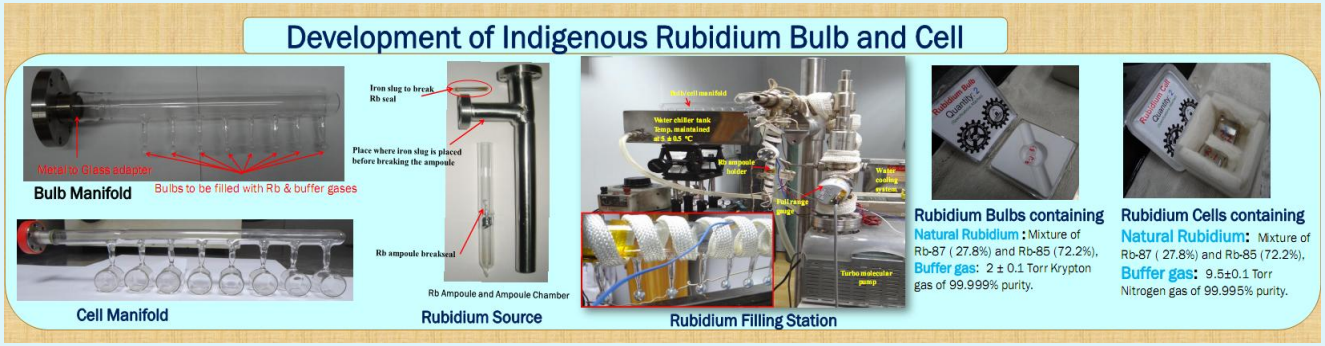
Rubidium Atomic Clock for Space



CSIR-NPL has developed and transferred the critical technology of Rubidium atomic clock for space applications to ISRO. A model has been developed at CSIR-NPL and is undergoing further developments at Satellite Applications Center before being integrated in the payload of the Indian Regional Navigation Satellite system.



Further critical process for development of glass technology of Rubidium bulbs and cells is under development at CSIR-NPL for making the indigenization of space clocks complete.

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TIME AND FREQUENCY DIVISION

Single Trapped Ion Optical Standard

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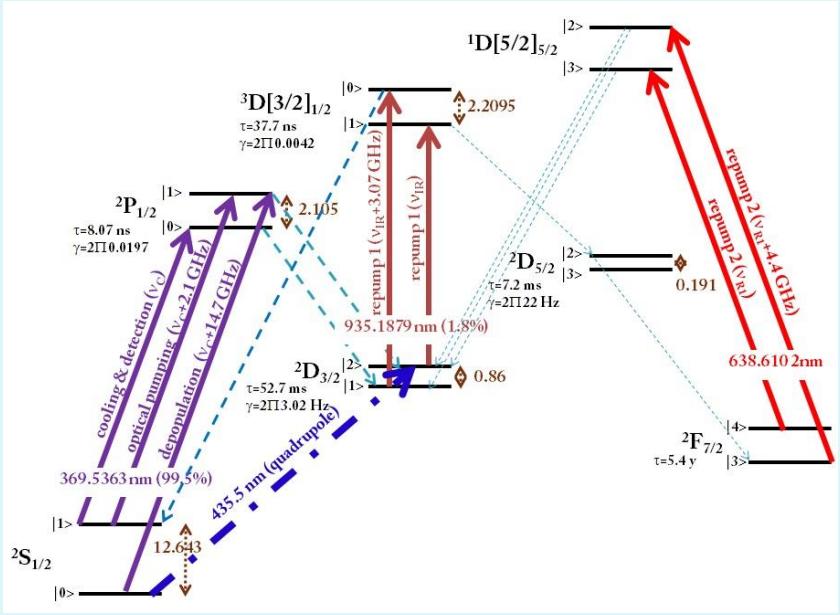

$^{171}Yb^+$ energy level diagram, energies are in GHz unit

Optical Frequency Standard

An optical frequency standard is based on optically probed narrow line-width electronic transition of some atoms or ions. An optical clock has much higher accuracy as it operates at few hundred *THz* frequency region compared to the conventional microwave atomic clocks. In NPLI, we are developing an optical frequency standard based on an ultra-narrow optical transition in single trapped Ytterbium ion ($^{171}Yb^+$). For $^{171}Yb^+$ the lowest lying excited state is $^2D_{3/2}$ which decays to the $^2S_{1/2}$ ground state via an electric quadrupole transition at 435.5 *nm*. The long lived $^2D_{3/2}$ state has natural decay time of several years, which leads to an extremely narrow natural line width (3.1 *Hz*) of that transition. A Paul trap will be used to trap a single $^{171}Yb^+$ and the temperature of the ion will be reduced to few micro Kelvin by laser cooling technique. A closed laser cooling scheme using 369.5 *nm* transition can be realized by implying two additional lasers at 935 *nm* and 638 *nm* for repumping. Finally fluorescence at 435.5 *nm* is will be used to drive the $^2S_{1/2}$ (F =0) - $^2D_{3/2}$ (F=2) clock transition, and the ion state will be determined by electron shelving technique.

CSIR - NPL

TIME AND FREQUENCY DIVISION

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4. Mr. A. K. Suri
5. Dr. Ashish Agarwal
6. Dr. Subhasis Panja
7. Dr. Poonam Arora
8. Dr. Subhadeep De
9. Mrs. Pranalee Thorat
10. Mrs. Suchi Yadav
11. Mrs. Preeti Kandpal
12. Mr. Mahavir Prasad Olaniya

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3. Mr. Ved Prakash
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Curriculum Vitae (*attached*)

Research interest :

- Maintaining time and frequency standards in India.
- Microwave frequency synthesis for atomic standards.
- Cesium fountain frequency standard.
- Optical frequency standards.

Kavindra Pant

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Curriculum Vitae (*attached*)

Research interest:

Power Electronics , Development of Analog and Digital electronic circuits etc. Presently involved in the development of Electronic circuits for Cesium Atomic Fountain Clock

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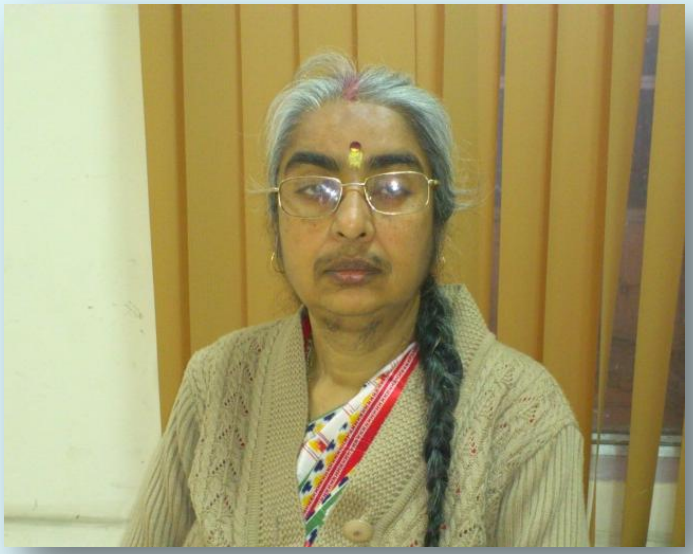
Curriculum Vitae (*attached*)



Research Interest:

Research and development on Time and Frequency activity

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TIME AND FREQUENCY DIVISION

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Curriculum Vitae (*attached*)

Research interest :

- Laser Physics, Quantum Optics and Nonlinear optics
- Time and Frequency Metrology
- Cesium Fountain Frequency Standard
- Rubidium Atomic Clock based Space Clocks
- Optical Frequency Standards.

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TIME AND FREQUENCY DIVISION

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Curriculum Vitae (*attached*)

Research interest :

- Time and Frequency Metrology: Development of single trap Ytterbium ($^{171}Yb^{+}$) ion optical frequency standards.
- Studies of isolated and solvated molecular ions in ion accelerators and in ion-storage ring and their optical spectroscopy.
- Ultrafast Laser pulse generation, Laser spectroscopy, White light generation, Photophysics and Photochemistry.

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TIME AND FREQUENCY DIVISION

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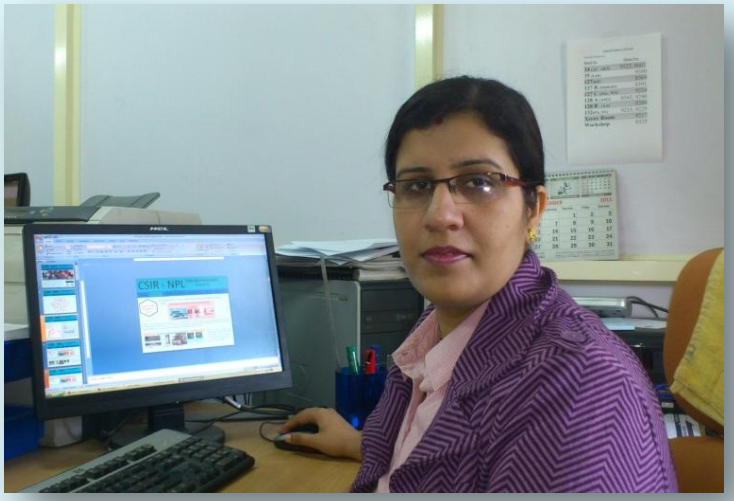
Curriculum Vitae (*attached*)



Research Interest:

- Time & Frequency Metrology
- Cesium fountain frequency standards
- Optical frequency standards
- Applied optics & Photonics, Lasers & quantum optics

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TIME AND FREQUENCY DIVISION

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Curriculum Vitae (*attached*)

Research Interest:

- Time and frequency metrology: building facility to trap single Ytterbium ion for an optical frequency standard (**STIOS** project at NPLI)**.**
- Studying many-body dynamics in Bose Einstein Condensate and Degenerate Fermi Gases.
- Studying quantum phases and phase transitions with ultra-cold atoms in optical lattice for the realization of qubit for quantum computers.

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Curriculum Vitae (*attached*)

Research Interest:

Currently involved in precise time & frequency activities viz. Teleclock service, Network Time Service, Implementation of PAN INDIA PAN TIME Concept, Time Scale Generation & its Improvement, Introduction of Kalman Filter Algorithm in the Time Scale, Precise Inter-comparison of remote clocks, Introduction of TWSTFT to link Europe and Asia, PTP Implementation, Identifying sources of errors and searching for their remedial measure in the time link etc., etc.

CSIR - NPL

TIME AND FREQUENCY DIVISION

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Curriculum Vitae (*attached*)

Research Interest:

Current activities are: Installation, operation & maintenance of Two Way Satellite Time & Frequency Transfer system, Installation, operation and maintenance of G P S receiver,Data analysis for P3 and PPP of gps, Time scale generation UTC-NPLI .

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TIME AND FREQUENCY DIVISION

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Curriculum Vitae (*attached*)

Research Interest:

•I am working in the area of maintaining Time scale UTC(NPLI) and its link with the BIPM using GPS satellites and Two-way satellite time and frequency transfer (TWSTFT).

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TIME AND FREQUENCY DIVISION

Find our photos at: https://plus.google.com/photos/108722323066025213151/albums

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