Evaluative Report of Raja Ramanna Centre for Advanced Technology

1 Name of the CI

Raja Ramanna Centre for Advanced Technology (RRCAT), Indore

2 Year of establishment

Please see para 6 of the 'Profile'.

3 Is the CI part of the university

Yes

4 Names of programmes offered

RRCAT offers M.Tech. in Engineering Physics and Ph.D. in Physical Sciences, Life Sciences, Engineering Sciences and Chemical Sciences. Please also see Appendix 1 of the profile.

5 Interdisciplinary programmes

Subject of research leading to Ph.D. is inter-disciplinary in many cases. M.Tech. in Engineering Physics programme run by RRCAT is also an inter-disciplinary programme.

6 Courses in collaboration with other universities, industries, foreign institutions, etc.

Ph. D. students can have two guides with one of them from a collaborating institution with whom HBNI has a formal MoU. For a list of collaborating institutions, please see Para 2.4.10 of 'Criteria-wise Inputs'. Additionally RRCAT has MoU with IIT, Indore and Devi Ahilya Vishwavidyalaya, Indore.

7 Details of programmes discontinued, if any, with reasons

NIL

8 Examination System

Semester system

9 Participation of the department in the courses offered by other departments

This question is not applicable to RRCAT. CIs of HBNI have no rigid boundaries. Development of advanced technologies being pursued at RRCAT involves inter-disciplinary teams.

10 Number of teaching posts sanctioned, filled and actual (Professors/Associate Professors/ Asst. Professors/ Others)

Please see para 24 of the Profile.

11. Faculty profile with name, qualification, designation, area of specialization, experience and research under guidance

Please see Appendix 1

12. List of senior Visiting Fellows, adjunct faculty, emeritus professors :

Please see para 26 of the 'Profile'.

13. Percentage of classes taken by temporary faculty – programme-wise information :

NIL

14. Programme-wise Student Teacher Ratio :

1: 2.7 for delivering lectures in PG-Diploma, M. Tech. and pre Ph. D courses. Guidelines of UGC with regard to number of research students a supervisor can guide are strictly followed.

15. Number of academic support staff (technical) and administrative staff: sanctioned, filled and actual

Please see para 24 of the 'Profile'.

16. Research thrust areas as recognized by major funding agencies

RRCAT is engaged in R&D work in front-line areas of accelerator science, technology, and applications. The Centre has indigenously designed, developed,

and commissioned two synchrotron radiation sources: Indus-1 and Indus-2, serving as a national facility. The Centre is pursuing several other key accelerator activities viz. development of a high energy proton accelerator for a spallation neutron source, electron accelerators for food irradiation and industrial applications, and free electron lasers (FEL) in tera-hertz (THz) and infra-red (IR) spectral region, and development of advanced technologies such as superconducting radio-frequency (SCRF) cavities and cryomodules, cryogenics, radio-frequency (RF) power, magnets, ultrahigh vacuum, precision fabrication, and control instrumentation to support the various R&D programmes.

RRCAT is also the largest Laser R&D Centre in the country. It is involved in the development of a variety of laser systems and their utilization for applications in industry, medicine and research. The laser systems developed include high power Nd: YAG lasers, semiconductor lasers, chemical lasers, excimer lasers, fibre lasers, high energy/ultrahigh intensity pulsed Nd: glass lasers, copper vapour lasers (CVL), and CVL pumped dye lasers. Crystal of a variety of materials of interest to laser technology have also been grown. The industrial applications being purused include cutting, drilling, welding, surface modifications, laser surface peening, and rapid manufacturing. A variety of laser based instruments for applications in industry, medicine, agriculture, nuclear reactors and other strategic areas have been developed. Both in-house developed and commercial lasers are being used in the frontline areas of research viz laser-plasma interaction in the high energy density regime relevant to laser driven inertial confinement fusion as well as in the strong field regime, laser cooling and trapping of atoms, non-linear optics, ultrafast dynamics, material processing, and laser bio-medical applications like spectroscopic techniques for detection of cancer, laser micromanipulation of microscopic objects and optical coherence tomography for non-invasive imaging of biological tissues.

Funding in all these areas of R&D activities is provided by the Department of Atomic Energy. For more details, please see para 3.1 of the 'Criteria-wise Inputs'.

17. Number of faculty with ongoing projects from a) national b) international funding agencies and c) Total grants received. Give the names of the funding agencies, project title and grants received project-wise.

Full funding is received from the Department of Atomic Energy and all the faculties are involved in one or more projects. Details of ongoing projects and grants for RRCAT put together are given in Appendix 2.

18. Inter-institutional collaborative projects and associated grants received

RRCAT is associated with several international projects including CERN; Fermi Lab., USA; LIGO – USA.

19. **Projects funded by DST-FIST; UGC-SAP/CAS, DPE; DBT, ICSSR, AICTE, etc.; total grants received**.

Nil.

20. Research facility / centre with

- **state recognition**
- **national recognition**
- **international recognition**

RRCAT has no formal recognition from any agency.

RRCAT houses India's first and only one Synchrotron Radiation Sources Indus-1 and Indus-2, which are national facilities. In addition there are several state of the art research facilities in the areas of lasers and accelerators at RRCAT, which are being used by researchers form Universities and Academic Institutions in India.

21. Special research laboratories sponsored by / created by industry or corporate bodies

HBNI is essentially a research university and research output of its CIs including RRCAT is deployed in industry, including industrial units and PSUs of the DAE. Many technologies are transferred to outside entities through a well established technology transfer mechanism. All research laboratories in RRCAT are sponsored by the Government for the purpose of deployment in the industry.

22. Publications:

Please see para 3.3 of the 'Criteria-wise inputs'.

23. Details of patents

A number of inventions have been patented. Please see Appendix 3 for a list.

24. Areas of consultancy and income generated

Not Applicable. Please see para 3.4 of the 'Criteria-wise Inputs'.

25. Faculty selected nationally/ internationally to visit other laboratories/ institutions/ industries in India and abroad

Visits within India are numerous and are not listed. For visits abroad, please see Appendix 4.

26. Faculty serving in
a) National committees b) International committees c) Editorial Boards d) any other (please specify)

Please see Appendix 3 of the 'Criteria-wise Inputs.

27. Faculty recharging strategies (UGC, ASC, Refresher / orientation programs, workshops, training programs and similar programs).

HBNI encourages faculty to participate in and organise national and international workshop and conferences, go to universities abroad for post doctoral fellowships and short term research assignments, act as consultants for developing countries under programmes sponsored by IAEA, participate in collaborative projects with universities in India funded by BRNS, participate in collaborative projects with laboratories abroad under various MOUs. All this helps to recharge the faculty.

28. Student projects :
- **percentage of students who have done in-house projects:** 100%
- **percentage of students doing projects in collaboration with other universities/ industry/ institute: 0%.**

Situation in RRCAT is actually reverse of what is there in other universities. More than 100 UG/PG students from other universities come every year to RRCAT for carrying out their project works.

29. Awards / recognitions received at the national and international level by
- **Faculty**
- **Doctoral / post doctoral fellows**
- **Students**

Please see Appendix 1 of the 'Criteria-wise Inputs'.

30. Seminars/ Conferences/ Workshops organized and the source of funding (national/ international) with details of outstanding participants, if any.

Please see Appendix 5.

31. Code of ethics for research followed by RRCAT

In addition to excellence in Science and Engineering, a strict adherence to high ethical standards is a necessity. The core ethical policy of DAE is to establish a tradition with highest ethical standards, ensuring a harmonious future for the entire humankind, where every individual can live with dignity and self-respect. In accordance with the guidelines of the DAE, adhering to highest ethical standards is one of the guiding values of RRCAT. Every complaint of malpractice or plagiarism received is investigated and appropriate action is taken.

32. Student profile programme-wise

Please see para 15 and para 28 of the 'Profile.'

33. Diversity of students

Please see Para 2.1 of the 'Criteria-wise Inputs'.

34. How many students have cleared Civil Services and Defense Services examinations, NET, SET, GATE and other competitive examinations? Give details category-wise.

Please see para 1.1.3 of the 'Criteria-wise Inputs. This question is not applicable to HBNI.

35. Student progression

Students joining BARC Training School at RRCAT become employees of DAE and at some stage come back to enroll for Ph.D.

36. Diversity of staff

Please see para 2.4.3 of the 'Criteria-wise Inputs.'

37. Number of faculty who were awarded M.Phil., Ph.D., D.Sc. and D.Litt. during the assessment period

Nil

38. Present details of infrastructural facilities with regard to

a) Library: Please see para 4.2 of the 'Criteria-wise Inputs'. The library has adequate physical facilities such as reading-rooms, repography, internet and is stocked with number of journals (172), books (10774 + 3452 Hindi books) and other library resources (i.e. CDs/ cassettes, etc.). In addition the Department of Atomic Energy (DAE) has set up a consortium to subscribe 2405 journals through Science Direct and these are available to RRCAT.

b) Extensive internet facilities are available to staff and students

c) Total number of class rooms: 5 Lecture Halls. Class rooms with ICT facility are also available. ICT available consists of the hardware, software, networks and media for the collection, storage, processing, transmission and presentation of information (voice, data, text, images) as well as related services.

d) Students' laboratories Yes

e) Research laboratories Yes

39. List of doctoral, post-doctoral students and Research Associates

Please see Appendix 6.

40. Number of post graduate students getting financial assistance from the university.

All students perusing their PG(Diploma), and Ph. D programme get financial assistance from the university. After a year in Training School students become employees and get salary.

41. Was any need assessment exercise undertaken before the development of new programme(s)? If so, highlight the methodology.
Please see para 1.1.2 of the 'Criteria-wise Inputs.

42. Does RRCAT obtain feedback from

a. faculty on curriculum as well as teaching-learning-evaluation? If yes, how does RRCAT utilize the feedback?

b. students on staff, curriculum and teaching-learning-evaluation and how does RRCAT utilize the feedback?

c. alumni and employers on the programmes offered and how does RRCAT utilize the feedback?

Obtaining feedback from faculty, alumni and employees is a continuous process. Feedback from students is obtained once every year at the end of the academic session. All feedbacks received is analysed and fed to an apex committee for deliberation and decision. Introduction of new programmes and changes in syllabus are decided as needed.

43. List the distinguished alumni of the CI (maximum 10)

The list below includes those, who received a Ph.D. based on the work done at RRCAT, or are from the Training School, but prior to the setting up of HBNI.

Sl. No	Name
1.	Dr. P. D. Gupta, Director, RRCAT
2.	Dr. P. A. Naik, Head, Laser Plasma Division, RRCAT
3.	Dr. L. M. Kukreja, Head, Laser Materials Processing Division, RRCAT
4.	Dr. G. S. Lodha, Head, Indus Synchrotron Utilization Division, RRCAT
5.	Dr. A. Banerjee, Head, BARC Training School at RRCAT

44. Give details of student enrichment programmes (special lectures/ workshops/ seminars) involving external experts.

RRCAT regularly hosts international experts to give seminars in their field of specializations. Several interaction meetings/workshops have been organized at RRCAT during last five years for utilization of the various state-of-the-art beam-lines in the Indus-synchrotron sources. In addition RRCAT has hosted the prestigious International Accelerator School for Linear Collider during the period November 27 – December 8, 2012, where several renowned international experts gave lectures to the selected students in the School.

45. List the teaching methods adopted by the faculty for different

programmes.

Besides standard class room teaching, interaction though discussions in laboratories.

46. How does RRCAT ensure that programme objectives are constantly met and learning outcomes are monitored?

Professional programmes conducted at the Training School prepare students for a lifelong career in DAE. Their successful outcome is demonstrated by the success of setting up of accelerators, developments in laser technology including its use for repair of reactors etc. These programmes have seen continuous evolution over the years in terms of updating of syllabus. Assessment of students includes end-semester viva voce which tend to look at what a student has learned in a holistic manner rather than subject wise. A mini project and viva voce following it evaluates problem solving abilities of students. It may be added that though not articulated formally so far, the expected outcome of programmes at BARC Training School is to equip its graduates to apply fundamental knowledge of nuclear science and engineering in day to day working in units of the DAE.

Quality of theses produced by doctoral students is demonstrated by comprehensive research abilities acquired by students. Invariably number of publications in peer reviewed journals coming out of a thesis varies from one to several as can be seen from previous annual reports. Students after their completion of PhDs are generally selected for employment (including as INSPIRE faculty) in national laboratories, universities or industry in India or abroad.

47. Highlight the participation of students and faculty in extension activities.

Please see para 3.5 of the 'Criteria-wise Inputs'. Further, faculty and students at RRCAT pursue various extension activities in the form of 'public outreach programme', 'project training programme' and 'young scientists' research programme'.

As a part of RRCAT public outreach programme, visits are arranged to RRCAT by students and faculty of colleges and schools. These visits are carefully planned keeping in mind the visiting group's level and interest, and usually last for 1-2 days with lectures, lab visits and demonstrations. The aim is to induce students to take up a career in science within the country by giving an overview

of the research going on at RRCAT and DAE, and also give an exposure to the excellent research facilities at RRCAT. During the year 2013-2014 small groups from the following institutes visited RRCAT:

1. IIT, Mumbai
2. IIT, Hyderabad
3. Rajasthan Technical University, Kota
4. NRI Inst of Research & Technology, Bhopal
5. Electronics & Communications Engg Dept, IPS Academy, Indore
6. H.S.Gaur University, Sagar

In addition, two major events were held. One was an open house on Feb 22, 2014 to commemorate the National Science Day. About 1600 students and teachers from 116 schools from Indore and nearby places visited specially prepared exhibits at 16 laboratories. The exhibits were designed to explain the scientific and technical activities of RRCAT and to demonstrate a number of basic science concepts. The second was the Vigyan Manthan Yatra. This was a visit by 106 VIII standard students of various schools of Madhya Pradesh selected by the Madhya Pradesh Council of Science and Technology (MAPCOST) on basis of merit. The students spent a day at RRCAT visiting labs and interacting with RRCAT scientists. They got some hands-on experience from experiments setup especially for them, illustrating basic scientific principles.

Under project trainee programme RRCAT offers opportunities to the students pursuing MSc/MPhil degrees in various science disciplines and ME/MTech degree in various engineering disciplines from recognized Institutes/Universities in India for carrying out project works for partial fulfillment of their degree. The selected students carry out the project individually under the guidance of faculty/scientific staff of RRCAT. During 2013-2014 total 134 students from various institutions across the country carried out their projects works under this programme.

Under the Young Scientists Research Programme (YSRP) students who are in the first year of MSc (Physics) programme or in the fourth year of integrated MSc(Physics) programme or in the third year of BE/BTech programme spend 8 weeks at RRCAT working on projects in the various front line scientific research areas under the guidance of faculty/scientific staff. The students selected in the programme are provided travel support in the form of train fare, free accommodation at RRCAT guest house and a monthly stipend of Rs.2500. During 2013-2014 total 10 students from various institutions across the country took part in the YSRP programme at RRCAT.

48. Give details of "beyond syllabus scholarly activities".

The faculty is continuously engaged in research necessary for meeting the mandate of the DAE. A significant percentage of this engagement is scholarly and results in good publications in peer reviewed journals. The students and faculty give lectures very frequently in various fora like national and international symposia, workshops, awareness programmes and colloquia. They interact on a regular basis with scientist and technologists of repute from the country and from abroad. They organise high level knowledge dissemination activities like organization of advanced schools under the aegis of BRNS/ DST and other similar bodies.

49. State whether the programme/ CI is accredited/ graded by other agencies? If yes, give details.

Yes, by UGC

50. Briefly highlight the contributions of RRCAT in generating new knowledge, basic or applied.

Due to a very large volume of very high quality basic and applied research being carried out by the faculty and the students, the research output is excellent and this gets documented in the form of publications in international journals, patents and reports. A brief description of some important scientific and technological developments is provided below.

Particle Accelerator Programme

(1) Indus-Synchrotron Radiation Sources

Raja Ramanna Centre for Advanced Technology, Indore has indigenously designed, developed, and commissioned two synchrotron radiation sources: Indus-1 and Indus-2, serving as a national facility. Indus-2 synchrotron radiation source is a 2.5 GeV booster synchrotron-cum-electron storage ring which is the largest and the highest energy accelerator built in the country. Presently, Indus-2 is operational at 200 mA beam current at its design energy of 2.5 GeV. Indus-1 is operational at its design parameters of 450 MeV energy and 100 mA beam current. The various components and sub-systems of these accelerators have been developed indigenously and most of them for the first time in the country.

Both the synchrotron radiation sources, Indus-1 and Indus-2, are operated in round-the-clock mode. 12 beamlines on Indus-2 and 5 beamlines on Indus-1 are commissioned and are being utilized by an increasing number of researchers

from universities, academic institutions and national laboratories. Work is underway to further upgrade the performance of Indus-2 and to install five insertion devices in its storage ring and build beamlines on them. These will provide synchrotron radiation of two to three order of magnitude higher brightness to the users and extend the photon energy range to 80-100 keV in the beamline based on superconducting wiggler.

RRCAT has developed a new technology of solid state RF amplifiers to replace non-functional klystrons powering the Indus-2 RF cavities for which problems were faced in procurement due to embargo enforced by some developed countries. The output power of solid state RF amplifiers has now been enhanced to 225 kW, thus eliminating our dependence on imported klystrons. Indus-2 is now regularly operated with the support of these solid state RF amplifiers. It may be mentioned here that it is for the first time in the world that high power solid state amplifiers at a frequency exceeding 500 MHz delivering more than 200 kW continuous power have been developed and successfully deployed in a synchrotron radiation.

(2) **Development of High Energy and High Intensity Proton accelerators**

In view the Department of Atomic Energy's long term programme on developing high intensity proton linacs for a spallation neutron source and accelerator driven system, a R&D programme has been launched at RRCAT for indigenous development of superconducting cavities, RF power, cryogenics and related infrastructure. A few single-cell niobium superconducting cavities have been developed at RRCAT under the framework of Indian Institutions Fermilab Collaboration (IIFC), which have shown excellent performance, meeting international standards. Further, a new technology of laser-welding of niobium superconducting cavities has also been developed and successfully demonstrated. This technology, developed for the first time in the world, offers many practical advantages compared to the conventional electron beam welding. RRCAT has also launched on the challenging task of developing large scale RF power for feeding superconducting RF cavities at still higher frequency of 650 MHz for our high intensity proton accelerator programme as well as for Project-X under the framework of Indian Institutions Fermilab Collaboration.

Modern day accelerators based on superconducting technology require liquid helium for their operation. Keeping in view the wide-ranging role of cryogenics in accelerator technology, an elaborate cryogenic infrastructure has been developed at RRCAT. A helium liquefier was indigenously developed at this

Centre for the first time in the country in August 2010. Other recent developments include cryocoolers, 2K cryostats, and large scale helium storage and recovery system. Special emphasis has been made on indigenous development of these devices to achieve self-reliance in this strategic area which may face technology restriction regime.

(3) Free Electron Laser

On the path of developing light sources with ever increasing brightness, free electron lasers (FEL) are considered to be the most advanced, i.e. fourth generation source. They even surpass the brightness of the synchrotron radiation emitted by insertion devices and have many applications ranging from basic and applied research in condensed matter physics, biological sciences, security systems and strategic interest. These lasers combine the principles of two advanced technologies of lasers and accelerators. RRCAT has developed a compact ultra fast terahertz free electron laser using indigenously built electron linac and undulator which is under commissioning. The first signature of build-up of coherence has been observed in this laser operating at 200 mm wavelength (1.5 THz). Work is also underway to set up an FEL in the infrared region and construct beamlines for materials research.

(4) Industrial Accelerators

Low and medium energy accelerators have also been set up at RRCAT. A 7-10 MeV, 3kW RF electron linac is being used for irradiation of food, agricultural and medical products. An optimized bremsstrahlung converter of tantalum has also been developed for irradiation in X-ray mode. Advantage of an accelerator based irradiation system is that there is no radioactive material (like Cobalt-60) and there is no radiation when the accelerator is not in operation. This facility has been used for a number of studies on mutation breeding with delivered dose in the range of 200-800 Gy.

(5) Accelerator Materials

Superconducting and magnetic materials are used in making many components and sub-systems in modern day particle accelerators; for example high speed pulsed magnetic devices play a crucial role in the functioning of synchrotrons and storage rings. A variety of ferrites with fast switching characteristics have been indigenously developed at RRCAT for use in Indus accelerators. Newer magnetic materials have been discovered with large magneto-caloric properties, which may lead to energy efficient and environment friendly cooling technology. Use of devices made from superconducting materials minimizes

the energy dissipation, thereby enabling construction of more powerful and compact accelerators. For example, niobium is used in making SCRF cavities to produce high accelerating gradients with very small loss. Scientific research being pursued at RRCAT has revealed that it may not always be prudent to start with a very high purity niobium material (which may be extremely expensive) as subsequent cavity processing steps may degrade the superconducting properties and eventually determine the cavity performance. Based on this scientific research a materials qualification method has been suggested to optimize the properties of superconducting materials and look for new options to develop SCRF cavities of high accelerating gradient and quality factor.

(6) Precision components for accelerators

Particle accelerators comprise of a large number of mechanical components which have to be specifically developed as per their stringent design specifications. A majority of them need to be UHV compatible and several of these are required to be fabricated from special materials with demanding dimensional tolerances (of tens of microns order) and surface finish (of sub-micron). RRCAT has set up an accelerator components design and fabrication unit which has grown into a facility of international standards. Some examples of the accelerator components made by this unit include dipole vacuum chambers of aluminum alloys which are evacuated to 10^{-10} mbar range, RF cavities for microtron, booster synchrotron and Indus-1 accelerators, superconducting RF niobium cavities and tuners, RF waveguides and couplers, linac structures for free-electron laser, plasma chamber for H- ion source, and a variety of mechanical assemblies for beamlines of Indus synchrotron radiation sources. Many components needing special fabrication have been supplied to CERN under DAE-CERN Collaboration under novel accelerator technology projects of LINAC-4 and CTF-3. It may be mentioned here that RRCAT has been the nodal unit of the DAE in implementing DAE-CERN Collaboration in building Large Hadron Collider (LHC) at CERN under which many hardware components were supplied.

Laser Programme

RRCAT, is the largest Laser R&D Centre in the country. It is involved in the development of a variety of laser systems and their utilization for applications in industry, medicine and research; some of these developments are briefly narrated below.

(1) Lasers for industrial and strategic applications

Laser cutting & welding for nuclear reactors : RRCAT has developed different types of highly efficient industrial Nd: YAG lasers as well as laser material processing technology including tools and fixtures for computerized remote operation for deployment in nuclear power programme, resulting in a much smaller radiation exposure of workers and enormous time and cost savings. RRCAT has commissioned 20 Nd: YAG lasers with remote control operation in different DAE units. Some of the notable applications are (a) Laser cutting of bellow lips during en-masse coolant channel replacement (EMCCR) in three pressurized heavy water reactors (PHWRs), (b) Laser cutting of irradiated fuel sub-assembly of fast breeder test reactor (FBTR), (c) Laser cutting of pressure tubes of zircaloy removed from reactors during EMCCR for easy storage, and (d) Repair of leaking weld-joint inside a reactor calendria. The technology and tools for underwater laser cutting of nuclear components (12 mm thick SS 304 and 4 mm thick zircaloy) have been developed. RRCAT has also developed an Nd: YAG laser based cleaning of zircaloy pressure tube, Inconel SG tubes etc. These systems have potential applications in decontamination of hot cells and walls of nuclear reactors.

Laser based instrumentation: RRCAT has developed a variety of laser-based instruments such as a portable uranium analyzer for uranium prospecting and for monitoring of effluents, computerized laser markers that can write on any material, a land leveling system, a laser based metrology system for quality assurance of nuclear fuel pellets and remote inspection of radioactive components, a fuel pellet density measurement system, and fibre-based temperature sensors.

Laser for strategic applications: RRCAT is also developing lasers for strategic applications. A diode-pumped frequency doubled Nd: YAG laser is being developed to meet requirements of Defense Research & Development Organization (DRDO) for a laser dazzler. Further, new laser techniques are being invoked in laser material processing to meet some strategic needs. RRCAT is collaborating with Aeronautical Development Authority in developing a laser surface peening system to enhance fatigue life of hydraulic components of Tejas aircraft. Similar collaborative efforts are underway with Bharat Heavy Electricals Limited (BHEL), Hyderabad, and Tata Motors, Pune on enhancing the fatigue life of turbine material and automobile spring steel respectively. Next, laser rapid manufacturing is being used to make specialized components of functionally graded materials and components required in defense, nuclear, aerospace and medical sectors.

(2) Lasers for biomedical applications

RRCAT has developed a number of laser systems for surgical applications. A surgical CO_2 laser system was developed for laser surgery which has been used at Choithram Hospital & Research Centre, Indore and All India Institute of Medical Sciences (AIIMS), New Delhi. A diode-pumped, frequency-doubled solid state Nd: YVO_4 laser based photo-coagulator has been developed and given to Arvind Eye Hospital, Madurai for treating diabetic retinopathy.

R&D on the use of lasers for bio-medical applications is being actively pursued at RRCAT. Extensive studies have been carried out to understand the difference in fluorescence from normal and malignant human tissues and a clinical evaluation of the approach, for detection of cancer of oral cavity, has been carried out at Government Cancer Hospital, Indore and Tata Memorial Hospital, Mumbai. For depth-resolved cross-sectional imaging of biological tissues, Optical Coherence Tomography (OCT) set ups have been developed and used for several studies including first demonstration of 3 D orientation of intracellular objects, laser assisted injection of genetic material or drugs into cells, malaria diagnosis with laser tweezers, guidance of neuronal growth cones with asymmetric laser tweezers etc. Detailed studies are also being carried out on the use of chlorine p6 and other photo-sensitizers for photo-dynamic treatment of infected wounds and cancer of oral cavity in animal models.

(3) Laser-plasma interactions and laser-based acceleration

RRCAT has set up a high power Nd: glass laser chain facility for studies of laser plasma interaction under extreme conditions of density and temperature, like equation of state of materials at tens of mega bar pressure and generation of intense thermal radiation in hollow gold microspheres at temperatures of ~10^6 K. The two arms of this laser deliver 200 J/1.5 ns and 25 J, 0.5 ps (50 TW) laser pulses. It is planned to upgrade this laser to carry out advanced studies related to laser driven inertial confinement fusion. A programme to indigenously develop phosphate laser glass rods and discs is underway at Central Glass & Ceramic Research Institute (CGCRI), Kolkata in collaboration with RRCAT and BARC. Next, a 150 TW, 25fs Ti-sapphire laser facility has been set up at RRCAT to carry out studies at ultrahigh intensities. Some important results of these studies include laser based acceleration of electrons to ~50 MeV energy and generation of coherent soft x-ray radiation as high order harmonic down to 109A^o wavelength. X-ray lasing at 46.9 nm in Ar^{8+} ions in a capillary discharge plasma has also been accomplished recently.

51. Detail five major Strengths, Weaknesses, Opportunities and Challenges (SWOC) of RRCAT.

Strengths

1. The quality of students is very good because of very rigorous selection process adopted. Since a vast majority of the students are scientists recruited by a tough selection process, a very high level of research output is ensured. This is contrary to the general trend seen elsewhere where students not finding employment are taking up research.
2. After a tough selection, the initial training imparted to the students is of very high standard.
3. The quality of research and infrastructural facilities available is very good.
4. The funding is very generous.
5. Besides the students, the faculty is also very strong, nationally and internationally known and there is very strong peer pressure on both the sides to do better.

Weaknesses:

1. Ensuring very high quality sometimes leads to very low number of students in some of the disciplines.
2. The embargo on supply of some items has resulted in lack of some of the sophisticated analytical equipment. This results in delays in research as alternate equipment has to be developed or innovative techniques have to be used for getting results.
3. Doctoral programme in engineering sciences has started expanding only in recent years. Faculty looks at themselves as scientists first and give lower priority to mentoring students. This is expected to improve over the years as faculty takes more and more students.

Opportunities

1. Opportunity to do high level research having immediate application in national programmes.
2. Opportunity to interact with scientist at national level and international level.
3. Opportunity to get various forms of national and international recognitions in the form of fellowships and awards.
4. Opportunity to develop various types of skills.
5. Opportunity to do interdisciplinary research.

Challenges

1. To balance various types of responsibilities for the faculty.
2. To balance between various types of responsibilities for the employees enrolled as students.
3. To publish results of research on strategic topics without compromising classified nature of information.
4. To ensure superiority in quality of research while doing doctoral research on large scale set ups.

52. Future plans of the RRCAT.

Expand the doctoral programme so as to utilise the full potential of the faculties and research infrastructure. Particular emphasis will be given to develop qualified human resources (both scientists and engineers) required for the rapidly developing fields of high energy particle accelerators and lasers in the country for energy, medical and industrial applications.

List of appendices (to be made available to the assessment team during their visit)

1. RRCAT: Appendix 1: Faculty profile referred to at para 11
2. RRCAT: Appendix 2: Ongoing projects referred to at para 17
3. RRCAT: Appendix 3: List of patents referred to at para 23
4. RRCAT: Appendix 4: Visits of faculties to International Laboratories/ Institutions referred to at para 25
5. RRCAT: Appendix 5: Seminar/ Meetings/ Conferences/ Colloquia referred to at para 30
6. RRCAT: Appendix 6: List of doctoral students referred to at para 39