# DOCUMENT III
# EDUCATION, TECHNOLOGY AND SCIENTIFIC EXCHANGE PROGRAMME OF THE INTERNATIONAL CENTRE FOR DENSE MAGNETIZED PLASMAS

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OF THE

# INTERNATIONAL CENTRE FOR DENSE MAGNETIZED PLASMAS

by

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and
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This document III has been prepared as part of a PROPOSAL DOCUMENT for the establishment of the INTERNATIONAL CENTRE FOR DENSE MAGNETIZED PLASMAS (ICDMP). The 4th Meeting of the INTERNATIONAL WORKING GROUP (IWG) met from the 24th - 28th March 1992 at Maxwell Laboratories, San Diego and considered this Document III as drawn up by S.Lee and K. Ware. The following document is the revised version of Document III which will be incorporated into a 5-part PROPOSAL DOCUMENT for the establishment of the ICDMP.

# DOCUMENT III: EDUCATION, TECHNOLOGY AND SCIENTIFIC EXCHANGE PROGRAMME

## A: Introduction

One of the most important functions of the Centre will be the cross fertilization of technological knowledge among the peoples and nations of the world in the general experimental research area of high power, pulsed electrical circuits and the generation and study of high density, high temperature magnetized plasmas. This Exchange Programme has been designed both through the functional activities of the educational programmes and into the physical functions of the Centre’s facilities. However the IWG recognizes the unlimited requirements for such a broad based undertaking even in the very limited technology area of pulsed electrical dense magnetized plasmas. The continuum of this specialized knowledge, like any other, goes from the most naive beginner to the incomplete mastery of the most seasoned expert. All of us are not only somewhere on this knowledge continuum but we are most likely at both extremes and elsewhere on the education path depending on what part of the "elephant" we are discussing. One may understand the quantum physical process leading to high density magnetized plasmas through radiation collapse but be unable to skillfully make a silver soldered joint for efficient high current flow or consider the design options to minimize triple-point electron flashover. "Every man, and woman, are in some way my superior, and in that I can learn of them". With this wisdom in mind, the Exchange Programme is loosely structured by programatically grouping the knowledge continuum into three recognizable activities to facilitate the exchange process.

The Exchange Programme will consist of three sub-programmes: 1)the Training Programme, 2) the Education Programme and 3) the Scientist Exchange Programme. The titles are not perfect but hopefully give a flavour of the technology exchange and enhancement envisioned. The Training Programme has been designed to teach the knowledge skills centred around making materials and hardware responsive to the technology required by the application of electrical pulsed power to the formation of dense magnetized plasmas. The programme will be both very basic in the skills and knowledge of electrical processes and advanced to allow the trainee to return to his home centre and establish an experimental facility for plasma research. This training programme will be detailed in Section B following this introduction. The Education Programme is designed to provide the proper environment at the Centre to support post-graduate accredited experimental and theoretical research and is discussed in Section C. The Scientist Exchange Programme is designed primarily to bring advanced experimental knowledge into the Centre through programmes of visiting specialists of pulsed power and dense magnetized plasma physics and is outlined in Section D. Section E estimates the cost and Section F discusses the impact of the programme.

## B. **Training Programme**

The Training Programme at the Centre has a general objective of increasing the awareness and activity of dense magnetized plasmas (DMP) research throughout the world particularly among the technologically developing countries. This would increase the scientific world-wide activities in DMP and provide an avenue for all nations to participate in the facilities of the ICDMP.

### B1. **Emphasis** and **Experience**

The Centre will take a pro-active approach to notifying the educational institutions, the governments and the industrial concerns of the developing nations of the opportunities in this programme with the ICDMP. Participants in this Training Programme will receive basic knowledge skills for pulsed electrical power and DMP formation at the Centre during on-site intensive programmes of six-month duration. They will become eligible after training to receive and take home to their home institutions each a small machine and basic diagnostic sub-packages. Other follow-up programmes described later in this section are also envisioned which will assist the graduating participants in this Training Programme to form research laboratories for DMP at their home institutions.

Experience has shown that for developing countries the training is most effective and has a lasting and multiplicative effect if it is integrated with the transfer of equipment, transferred as open, as opposed to black, 'boxes'. Such an exercise is only possible logistically if both the elements, training and equipment, are specifically designed to be cost-effective. An expanded training programme, and plasma physicists world-wide could benefit immensely from a Technology Resource Centre developed as part and parcel of the training programme of the ICDMP. Existing packages of plasma focus machines and diagnostics (e.g. soft x-ray spectrometer, N-laser shadowgraphy, neutron yield monitor) could be supplemented by other cost-effective yet advanced diagnostic packages to be contributed by more advanced research institutions.

The experience described above comes from an international training programme in plasma focus technology that already exists. This is the effort of the Asian African Association for Plasma Training (AAAPT) head-quartered at the International Centre for Theoretical Physics (ICTP) Affiliated Centre, ICAC-UM, in Kuala Lumpur. Funded originally by the United Nations University and now by the ICTP, the existing scheme has an integrated programme of training ( 2-6 months, very intensive programme) with a follow-up equipment package consisting of a 3 kJ plasma focus machine and some diagnostic sub-packages. This scheme has to date initiated plasma focus research in ten institutions in Sierra Leone, Nigeria, Egypt, Pakistan, India, Thailand, Indonesia and P.R.China up to Ph.D. and professional levels. A 3 kJ plasma focus from this programme has also been installed at the ICTP Laser Laboratory and has been used for research training by a team of 18 scientists from 11 countries in the 1991 Spring College on Plasma Physics. A 16 kJ theta pinch experiment to study implosion and reconnection dynamics and plasma spectroscopy will soon be installed also at the ICTP Laser Laboratory by the AAAPT to add to this international programme.

Scientists in many developing countries have just started to do research in small plasma focus machines e.g. Nigeria, Sierra Leone, Thailand and Indonesia to name a few representative cases. Many other groups e.g. in Iran, Syria, Zimbabwe, India, Pakistan and Kenya would like to start such research if they could acquire a small plasma focus or another simple plasma machine together with the appropriate training. Assistance to provide an integrated package of equipment and training to these groups would be most useful.

At higher levels there are other countries which whilst already having an established plasma programme may still benefit from the bigger machines and more sophisticated facilities of the proposed ICDMP or a network of laboratories offering such facilities to the ICDMP for a coordinated training programme.

B2. **The Plasma Focus- a superior device for training**

The plasma focus is an excellent device for teaching plasma dynamics and thermodynamics besides being a rich source for a variety of plasma phenomena including production of soft x-rays, particle beams and plasma nuclear fusion. From the point of view of a small cost-effective device it is certainly superior to both the electromagnetic shock tube and the linear Z pinch in its range of plasma parameters, combining as it does the essential features of both devices in such a properly sequenced manner that the features of the electromagnetic shock tube and the pinch, and many more additional features may be produced in one single simple low-cost device, when properly designed.

As a spectroscopic source its range has no equal. It may be run as a shock tube down to a speed of 1 cm per microsecond in Argon allowing ArI and ArII lines to be measured at a temperature of 20,000K. This speed may be increased in the axial phase up to 10 cm per microsecond with temperatures in excess of 400,000K, and then in the radial collapse phase the temperature may be boosted to 10,000,000K, thus in one device covering a controlled range of 10,000K to 10,000,000K at high densities.

A major advantage of the plasma focus as a training device is that the plasma condition (temperature and density) in a small, say 1 kJ machine is almost identical to that in a big, say 1 MJ machine. This is of particular significance to scientists from small developing countries as they may be trained in 'expensive' machines and may then continue their work back home in low-cost small machines with identical plasma conditions; so that their research remains relevant and competitive. Moreover plasma focus applications such as x-ray microscopy and lithography may best be studied on small devices.

## B3. **Other Pulsed Plasma Devices**

In addition to the plasma focus many more simple plasma devices could be developed as training devices e.g. the theta pinch to study laser diagnostics or spectroscopy, exploding fuses for power conditioning, exploding foils, flashboards or surface discharges to pump lasers like molecular Iodine (IR) or atomic

Iodine (UV).

B4. **Modules of learning**

Complementary to the training packages dedicated to single devices like the plasma focus or the theta pinch, trainees could also be given the benefit of modules of training as a preface to their acquisition of a full follow-up plasma facility. In these modules a trainee learns basic hardware skills like soldering, microfabrication, electrical wiring, use of multimeter and oscilloscope, digitizers, data acquisition systems, vacuum systems, leak detection, safety procedures, high voltage and current techniques, triple point breakdown, insulator flashover, radiation shielding, optical and spectroscopic techniques, gas handling and other techniques and basic skills useful for designing, building, maintaining and operating pulsed plasma facilities. A carefully structured sequence of proven modules would be very useful to develop the technical skills of the trainee. In addition some of the modules may be designed around the building of something useful e.g. a line driver in the soldering module, a filtered array of calorimeters, a power supply, a high voltage probe and others.

B5. **Structure of the Training Programme**

The specific objective of the Training Programme is to initiate research in DMP in institutions which have demonstrated the willingness and capability to participate in DMP research on being given the basic experimental facilities with manpower training; and/or to strengthen further the research manpower in such institutions.

To achieve this objective the ICDMP Training Programme will be a 6-month intensive programme consisting of two parts each of 3-month duration. For a start the programme will be based on the plasma focus. Part I will be basic training consisting of basic skills imparted through **modules of learning** already described above, basic plasma focus principles, computation and diagnostics together with design, assembly, testing and bench-marking of a small 3 kJ plasma focus. Part II will be research training. For a start during Part II for one month the trainee will join the on-going research work being carried out by scientists on the main plasma focus installations at the Centre. It is emphasized that whilst the objective of this one month of research training is to give the trainee a hands-on taste of 'real' research in practice it is possible for the trainee to actually achieve some research results if the fitting-in of the trainee into the on-going research programme is done carefully and with special consideration. For the second month of Part II the trainee will be set a small research project to be carried out on the 3 kJ machine and diagnostic facilities that he has set up during Part I and which will form part of his follow-up equipment. This 1 month of nearly independent research will set the tone of how the trainee will operate using the same facilities back home. The final month of Part II will be spent writing a report of the research (jointly with other trainees) and also in preparation for the shipment of the focus facilities and diagnostics back to the trainee's home institution. This preparation for shipment is crucial as it is during this period that the trainee has to ensure that he has all the bits of technology as well as all the parts that he will need back home.

We envisage a total of 6 trainees for each training programme with two training programmes per year. The implications of these numbers should be reflected not only in the financial provisions but also in the provision of staff. Three technicians (one pulsed power, one electronic and one machinist) will have to be assigned 1/3 of their time to this training programme. The actual 'trainers' will consist of one full-time scientist spending 1/2 his time and five other full-time scientists each spending 1/10 of his/her time on the training. Thus the manpower required for the training programme is equivalent to one full-time technician/engineer and one full-time scientist.

In keeping with the objective that the training programme is primarily to initiate research in the home institution, one crucial element is the selection of suitable candidates based on the consideration of not just the candidate but also the home institution. Thus a **site visit** to interview and assess the potential candidate and the home institution has to be carried out before the training programme. During the site visit the motivation, scientific capabilities and other relevant characteristics of the candidate should be ascertained. The candidate should preferably already have a Ph.D. in an experimental field with some relationship to DMP. Further the presence of adequate infrastructural support e.g. mechanical and electronic workshop facilities and the degree of long-term support for the candidate and the proposed DMP project shown by the institutional authorities should also be assessed and taken into account before a candidate is accepted into the Training Programme.

B6. **Complementary Activities**

Several types of activities may be envisaged which could play active roles to motivate the initiation or expansion of activities.

**On site orientation touring groups**

Groups of ICDMP trainees may be organized to tour several laboratories through some areas of the USA or Europe. In these tours the trainees would be more than just seeing the facilities or experiments, but less than working on the projects. They might spend a day or two at a facility to learn about it in some depth, not the physics of the plasma, but more of the applications of the blocks of technology learned in the modules of learning. Such a tour would certainly create a high level of interest in plasma research.

**On site Laboratory cultivation visit**

This might be considered as a converse to the above idea. Here a team of senior experimentalists (perhaps retired) would join efforts to set up a small experimental laboratory at a host university in a developing country. This would have the effect of training a whole group of people and providing them with a laboratory which they have helped to develop. This foundation effort could then be consolidated by periodic visits to provide lecture and experimental activities complementary to ICDMP activities.

**Video Library at ICDMP**

Video tapes could be made at major facilities like LLNL Nova facility or Tokamak T-15. These tapes could include full briefing on the facilities and would be very useful to broaden the outlook of the ICDMP trainees.

## C. Education Programme

The Education Program part of the the Centre’s Exchange Programme is a little easier to describe because it is patterned after the many fine national research centres in the world that have opened their doors to support graduate and post-graduate studies in association with universities and colleges. Only the international nature and the principal objective of research makes the ICDMP unique.

We propose that students accepted to the Programme for the degree of Ph.D. with certain universities and colleges be allowed to do their experimental and theoretical thesis work at the ICDMP. The Centre will have permanent scientific staff to provide the faculty type role for the students. Additionally exchange scientists from all over the world working on DMP will enrich the scientific cultural atmosphere for the students.

The size of the programme will of course be dependent on the size of the scientific staff of the Centre. In consideration that the primary role of the scientists at the Centre is to carry out research on the main DMP facilities it would appear that each scientist should supervise not more than 1 to 2 Ph.D. students with the number being on average closer to 1 Ph.D. student per scientist. An estimate of time spent per scientist on this duty would be approximately 1/5 of his time. We also estimate that there will be six Ph.D. students working at the major DMP facilities at the Centre; and that the same six full-time scientists mentioned as partially engaged in the Training Programmes described in section B5 above will also be supervising these Ph.D. students. Thus of these six full-time scientists, one will be spending 70% of his time and the other five will be spending 30% of their time on the Training Programmes and the supervision of Ph.D. students. This balance of duties appear quite satisfactory. Apart from the full-time staff who is in over-charge of the Training Programmes and who thus will have only a little time left for research, the other five full-time scientists will have about 60% of their time left for research, assuming they require 10% of their time for administrative duties. This 60% of their time spent on research is further enhanced by the fact that Ph.D. supervision is often very much also research and that further the Ph.D. students may also be used to assist in the Training Programmes.

## D. **Scientist Exchange**

Besides the six full-time scientists already mentioned under Sections B and C above we envisage that at any one time there will be six exchange scientists at the Centre. These exchange scientists may be on research assignments at the Centre for durations of three months to one year. Generally these scientists are expected to come from the many institutions world-wide which are actively carrying out research on DMP related to the research currently being carried at the ICDMP. They will be selected on the basis of the relationship of their current research to the on-going research at the ICDMP. These Exchange Scientists will also be able to assist in the Training Programmes and bring additional perspectives to the on-going Ph.D. programmes.

## E. **Cost of Programme**

We now make an estimate of the additional cost to the ICDMP of running the Training, Education and Scientist Exchange Programmes. In this estimate we shall not consider the fixed capital cost on site, building and equipment including office and laboratory space and other infra-structural requirements which we shall assume to have been provided for including the needs of these programmes. We shall not estimate the additional scientific and technical manpower requirements for training and supervision and shall assume that these have been integrated into the provisions of manpower requirements of the ICDMP. We shall only estimate here the stipends and miscellaneous costs of the trainees, the Ph.D. students and the Exchange Scientists and the follow-up equipment cost of the Training and Education elements of the Programme.

**Cost per year:** (USD)

| | |
|---|---|
| Trainees (6 man-year @ 14,000 stipend) | 84,000 |
| Ph.D. students (6 man-year @ 14,000 average stipend) | 84,000 |
| Exchange Scientists (6 man-year @ 25,000 average stipend) | 150,000 |
| Travel, start-up, insurance, misc. costs (30 return trips) | 60,000 |
| Misc. research materials (@5,000 per man-year) | 90,000 |
| Follow-up equipment packages(30,000 x 8) | 240,000 |
| **TOTAL:** | **708,000** |

This estimate is based on the **ICDMP being sited in a developing country**. If it were sited in a developed country the stipend could be estimated to require an increase of 50% on average so that the first 3 items above would rise from 318,000 to 477,000 and the total cost of this programme could then be estimated as 867,000.

## F. **Impact**

The impact of this Training, Education and Scientist Exchange Programme could be assessed. There would be a flow-through of some 10 to 15 exchange scientists a year. These are mainly at a scientific level of high calibre and the exchange of scientific and technological knowledge between these scientists and the full-time scientists, trainees and students at the Centre would be substantial. There would also be a production of two Ph.D.s a year and this would increase the manpower of DMP scientists particularly in the developing countries.

The Training element of the Programme is the one that will have potentially an even greater impact. This programme with its crucial follow-up equipment packages could **initiate and strengthen up to between 5 to 10 new research laboratories per year** in the area of dense magnetized plasmas and pulse power technology. This will have an immense accelerating effect on the education and research of these frontier technologies and physics particularly for the developing countries.

Additional note:

**Estimate of Manpower and recurrent cost for the ICDMP**

These estimates are made assuming that the ICDMP is to be sited in a developing country. The number of staff has already been discussed at the IWG at San Diego. I have included 2 clerical staff. The following gives an estimate of the cost.

| | | | **USD** |
|---|---|---|---|
| Manager: | 1 | | 40,000 |
| Operational Manager: | 1 | | 30,000 |
| Secretaries: | 2 | (@12,500 average) | 25,000 |
| Clerical: | 2 | (@10,000 average) | 20,000 |
| Physicists: | 10 | (@40,000 average) | 400,000 |
| Engineers: | 2 | (@35,000 average) | 70,000 |
| Technicians: | 10 | (@20,000 average) | 200,000 |
| Trainees: | 6 | (@14,000 man-year average) | 84,000 |
| Ph.D.students: | 6 | (@14,000 average) | 84,000 |
| Exchange Scientists: | 6 | (@25,000 man-year average) | 150,000 |
| **Total:** | **46** | | **1,103,000** |

We could estimate that **miscellaneous research materials** cost would be 5,000 for each scientist and trainee totalling 5,000 x 28 = **140,000.**

**Travel, insurance, start-up and misc. expenses** for the **non full time staff** may be estimated at 2,000 x 30 = **60,000.**

**Travel, insurance and misc. expenses** for the **full-time staff** may be estimated as 2,500 x 12 = **30,000.**

Thus the **recurrent annual cost related to manpower** is estimated as: **USD1,333,000.**

If we **include the follow-up equipment** for the Training Programme which is estimated as 30,000 x 8 = **240,000** then the **annual recurrent cost related to manpower and the training programmes (including follow-up equipment)** becomes: **USD1,573,000.**

The above estimate is for siting at a developing country.

If the **ICDMP were sited in a developed country** we could estimate that the salaries and stipends need to be **increased from the above table by an average 50%.** The salary and stipend total would then become **1,654,500;** and the **annual recurrent cost related to manpower and the training programmes (including follow-up equipment costs) would become :USD2,124,500.**