control of the vehicle and the health of the Orbiter subsystems, and two payload crew members (one Mission Specialist and one Payload Specialist) in the Spacelab module.

Payload Crew Training

Our training started right after selection in the middle of 1978. In an early phase, the crew travelled to a number of research laboratories in Europe and the United States, and was briefed by the Investigators of nearly every experiment on their scientific objectives. General lectures were also given, at the request of the crew, to provide a general understanding of the various disciplines involved.

This phase was followed, from mid-1979, by what I would call an operational phase, in which the crew had the opportunity to visit, a limited number of the same research laboratories where the Investigators and their teams had, in the meantime, assembled models, prototypes or training versions of their experiments. The crew had then the opportunity of learning to handle equipment that was, for the most part, very similar to the Flight Units that will soon be delivered by the Investigators to ESA and NASA. These training sessions were very fruitful, and operational concepts and procedures evolved substantially as as result of the knowledge and experience gained.

The operational phase is not ended yet, but due to the postponement of the mission, a slippage has also occurred in the development and preparation of experiments, to such a point that a hiatus of one year has now been inserted in the training plan of the payload crew, from July 1980 to July 1981. There has been, and will be no or very little payload-related training for our mission during this period.

Following negotiations between ESA and NASA, the latter has accepted to train during this year, two European Payload Specialists (including the author) as Mission Specialists at the Johnson Space Center. This training includes academic-type courses on manned spaceflight related subjects, technical courses on the Space Shuttle, technical assignments, and extensive flight training on NASA's T-38 jet aircraft as part of operational and environmental training.

On July 1981, our payload-related training will be resumed and will concentrate on the use of an off-line crew training facility at the Marshall Space Flight Center, Huntsville, Alabama. We shall also be involved in the on-line experiment integration phases in Europe and at the Kennedy Space Center. As in the past, our interaction with the Investigators will remain active to ensure an optimization of the payload operating procedures that are likely to evolve until a few months before flight. The mission itself will be the ultimate test of the thoroughness and quality of our training.

Optical Bistability
Towards the All-optical Computer

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An optical bistable device is one which has two states of transmission for one input intensity. With increasing incident intensity it can, at a given value "switch up" to a state of high transmission and stay in this condition, even if the incident intensity is significantly reduced. On further reduction, however, a specific point is reached when it "switches down" to a lower transmission level and output intensity is dramatically cut. The transmission state of the light beam providing the "holding power" can thus be read out from the ouput intensity of a pulsed beam addressed to this "all-optical memory".

The basic element is a parallel sided Fabry-Perot resonator filled with a medium whose refractive index depends on the applied light intensity. It operates as shown in the Figure. At low incident intensity, the resonator pass frequency is detuned upwards in respect to the frequency of the incident laser beam. As the laser intensity I is increased, the optical thickness increases: $nL = (n_1 + n_2 I)L$.

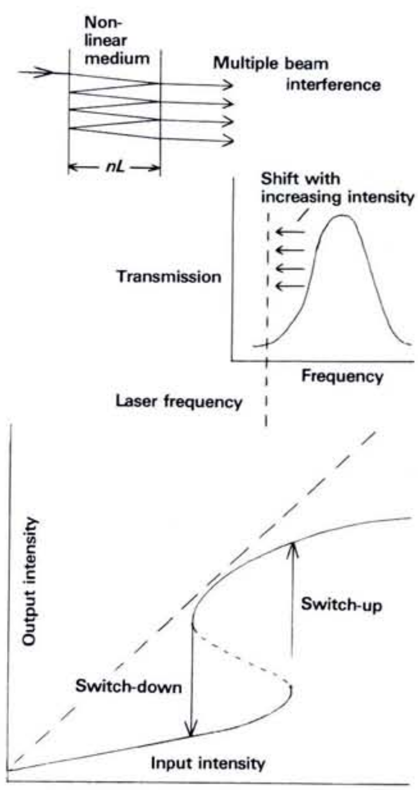
The result is that the resonator pass frequency is pulled towards the laser frequency. Then as interferometer resonance is approached, the intensity within the resonator also increases which in turn changes the refractive index and hence optical thickness ever more rapidly. At first the output/input curve becomes supra-linear and then eventually acquires a negative slope. At this point the device becomes unstable and the transmission jumps discontinuously to a value near the maximum possible. On reducing the power of the incident beam, the internal field is already established and remains high down to a level that is less than that at which "switch-up" occurred. This produces the hysterisis effect required for the optical memory.

Using two input beams, with a slight detuning of the laser frequency in respect to the resonator frequency, allows the output-input characteristic to become the direct analogue of the transistor and so give signal gain. This "three terminal optical circuit element", which operates by transference of optical phase thickness, is known as a "transphasor".

Based on the principles outlined above, the range of devices which have already been produced includes memories, amplifiers, AND and OR gates, pulse clippers and power limiters so that, in principle, the all-optical computer circuit elements needed to construct an all-optical computer have been demonstrated in the laboratory.

Historically the idea of optical bistability was advanced by Abraham Szöke and colleagues from M.I.T. They attempted to demonstrate *absorptive* bistability but it was not until 1975 that Sam McCall and Hyatt Gibbs at Bell Laboratories established *dispersive* bistability in a sodium vapour-filled interferometer. Devices based on this principle are large and slow and recent progress dates from the discovery in 1978 of giant non-linear effects in the semiconductor InSb by David Miller and colleagues at Heriot-Watt University, Edinburgh. This was applied to bistability in 1979 simultaneously with the Bell group's observations in GaAs.

The use of semiconductor materials has brought a considerable breakthrough with many new experiments now possible utilising a third order non-linear susceptibility:



$\chi^{(3)} (w; w, -w, w)$ of around 1 esu — some 8 orders of magnitude higher than usual! This corresponds to a change in refractive index of ~ 0.1% for 1 W/cm². Theoretically the subject has attracted much attention with early work by Rudolpho Bonifacio and Luigi Lugiato in Italy being continued and joined by Pierre Meystre in Garching, to mention only two of the theoretical papers from Europe presented at the First International Conference on Bistability recently completed in Asheville, North Carolina. Theory does not always relate closely to experiment, however, but ideas abound and the subject will certainly expand excitingly in the next few years.

An intriguing question that can now be posed is: will an all-optical computer compete in practice with microelectronic VLSI and Josephson junction devices? It is too early to give an answer as yet but there already exist positive features of both a qualitative and quantitative nature. First, qualitatively, the optical devices are based, at their simplest, on the non-linear Fabry-Perot etalon already discussed. This is two-dimensional in character so that image processing is possible in principle. Additionally, multistability with more than two stable states has already been demonstrated. Thus, optical processors can conceptually go beyond 1-dimensional sequential binary logic for their modus operandi.

The next considerations concern power, size and switching times which are to some extent related to each other. Normal electronic devices are intrinsically limited by electron transfer times across junctions to times around 1 nanosecond, whereas the latest field effect transistors can reach 50 ps and Josephson junctions (limited by electromagnetic propagation) can go down to ~ 20 ps. Optical devices made from Fabry-Perot resonators of micrometric dimension are limited by two factors — macroscopically, the internal resonator field build-up time, which is of the order of a picosecond for a device of ~ 10 µm in length, and, microscopically, the response of the non-linearity which is needed to obtain bistability. In practice this is also likely to be of the order of picoseconds for "switch up", depending on how much power is applied but may be longer for switch down. Even in high refractive index semi-conductors, light can travel ~ 1 mm in 10 ps so propagation delays should be comparable with or better than those to be obtained from Josephson devices.

Keeping the bistable switch near operating point requires a holding power for which, at present, the best value is 8 mW, i.e. of the order of µW/µm. Switching energy limits of femto-Joules (10^{-15} J) are predicted for devices of the limiting cross-section λ^2, where λ is the wavelength of the light (~ 0.25 - 1 µm inside the material).

At the very least, optical bistability offers the possibility of having all-optical switching elements for integrated optics with a performance comparable to normal electronic switching; at best it may give a new option for high speed data processing in the longer term.

ASDEX

A Step Towards Impurity Control in Fusion Experiments

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One of the most severe problems in controlled nuclear fusion based on magnetic confinement of a hot plasma, is the contamination of the hydrogen plasma by heavy atoms, such as iron, from the walls of the vacuum vessel. These impurities can strongly enhance the radiation losses (by line radiation, recombination and bremsstrahlung radiation) thereby affecting the power balance of the plasma. A simple energy balance consideration shows that for ignition of a deuterium-tritium plasma, the maximum tolerable iron concentration is 10^{-3}, while for the heavier tungsten the limit is 10^{-4}. A second unfavourable effect of the impurities is that they increase the gas-kinetic pressure of the plasma thus reducing the reacting fuel density when the total plasma pressure is limited. This also applies to the helium ash that results from the fusion process itself and which therefore has to be pumped preferentially.

The Divertor Concept

One of the most promising methods for impurity control is the magnetic divertor, a scheme that was proposed almost 30 years ago by L. Spitzer at Princeton[1]. External currents divert the confining magnetic field outside the plasma surface and conduct it to a separate chamber (divertor chamber). Charged particles that are lost from the bulk plasma follow these diverted field lines into the divertor chamber where they are neutralized (on neutralizer plates) and pumped off (e.g. by strong getter pumps). At the same time, the divertor boundary layer can shield the plasma core against wall-originated impurities by ionizing them and sweeping them into the divertor along with the outflowing plasma.

ASDEX Device

In Europe, DITE at Culham, UK and ASDEX at Garching, FRG are the only experiments in which the divertor concept of impurity control is being tested. While DITE is equipped with a bundle divertor (only a small bundle of magnetic field lines is diverted), ASDEX (**A**xially **S**ymmetric **D**ivertor **EX**periment) employs a poloidal divertor in which the total poloidal flux outside the plasma is diverted, i.e. charged particles reach the divertor along field lines after a few revolutions around the major circumference. This scheme thus guarantees a short path for particle transport into the divertor and also preserves the axisymmetry of the tokamak configuration.

ASDEX is a large toroidal device of the tokamak-type[2]) which was constructed during the past six years at a cost of about 40 Million DM (with strong financial support from Euratom) and started operation early this year. The plasma ring has a major diameter of 3.3 m and a minor diameter of 0.8 m. A plasma current up to 500 kA heats the plasma to about 10 M degrees. (In 1981 the injection of high energy neutral hydrogen atoms will allow a further increase in this temperature by a factor of up to five.)

First Experimental Results

In order to be able to assess the improvements in plasma purity by the divertor, the magnetic field configuration of ASDEX is designed in such a way that diverted and undiverted plasmas of equal size and cross-section can be compared. A pair of circular half-limiters, that can be retracted without breaking the vacuum, allows the passage from mechanically (limiter) to magnetically (divertor) defined plasmas between shots. In all, four types of tokamak discharges have been compared keeping the plasma parameters as similar as possible: Limiter, i.e. the standard tokamak mode (in the following denoted by L); Limiter with titanium gettering in the divertor chamber (LP); Divertor — limiter