An alternative to changes in the oceanic source might be changes in the glacial atmospheric circulation of the antarctic regions favoring the inland transport of marine aerosols to the central plateau from highly productive high-latitude coastal regions. Research is continuing to differentiate between these scenarios.

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# Development of laser ice-cutting apparatus

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During the 1990–1991 field season at Windless Bight near Ross Island, our team introduced the use of a 25-watt continuous infrared carbon-dioxide laser as a field device to cut individual firn cores for sample preparation. The test was successful and permitted this device to be employed on a routine basis in field operations. The advantage of carbon-dioxide, laser cutting systems is that the beam is emitted at an infrared wavelength, which is absorbed in a very short distance in ice. We were able to demonstrate conclusively that the laser beam can cut cleanly and rapidly through both firn and ice and that it can be manipulated efficiently with standard optical systems.

Subsequently, upon our return to the laboratory at the University of Kansas, we tested the system on a 10-centimeter diameter ice core from the Greenland ice sheet taken at a depth of about 170 meters (Koci personal communication). The core was supplied to us by P. Grootes. In this case, cutting was performed in an open freezer. The initial temperature of the core was approximately −20 °C. Total power output used was about 15 watts. The cutting was performed without optical condensers; we used the beam directly from the laser and were able to slice off a 5-centimeter segment of the core without shattering or fragmentation of any kind. The cut was about 2 millimeters wide and could have been reduced to half that width with an optical system. A videotape taken in the laboratory at the time of the cutting experiment was prepared and sent to the Division of Polar Programs at the National Science Foundation and to the Polar Ice Coring Office.

In the process of completing this experiment, we determined that it would be possible to develop an optical system that would permit the beam to be rotated in a circular path, a motion that could be used for cutting deep ice cores. With minor modifications, this system could be used in fluid-filled holes as well as in open holes.

The fact that the laser beam cuts entirely by melting and exerts no torque on the ice at the cutting surface, greatly reduces the potential for fracturing and breakage of the core during drilling. Even more important, because the beam can be deflected at 90° to the drilling directions, the ice core can be cut off at the bottom of the hole by the beam. This has the effect of greatly reducing stress on the core at the time it is lifted free of the bottom of the hole. Finally, contamination is avoided, first because the laser beam cannot introduce chemical contamination and, second, because the infrared wavelengths used for drilling are too long to cause significant radiolytic breakdown. Thus, chemical alterations of all types are kept to an absolute minimum.

In construction of a prototype, the rotating mass of the optical system and the thin-walled core barrel will be so low that only the lightest of anti-torque systems must be used. The entire drill assembly including the laser, optics, core barrel and scavenger pump system can be expected to weigh less than 90 kilograms and can be supported on a light-weight cable that must include electrical conductors for the 28-volt power supply to the laser. Power requirements are modest. Electrical power to the completed system can be supplied by a 3,000-watt generating facility and should be fully adequate for all operations including drilling and hoisting of the drill and core barrel assembly.

The simplest drill design is shown in figure 1. In this design, the carbon-dioxide laser is mounted vertically in the borehole and a rotating head containing deflecting mirrors is attached so that the laser beam can be directed down against the ice and turned in a circle by a small, low-power, direct-current motor. In principle, it is possible to design the drill so that the radius of the core is adjustable, but we propose to build a system with a fixed-core diameter (most probably 10 centimeters).

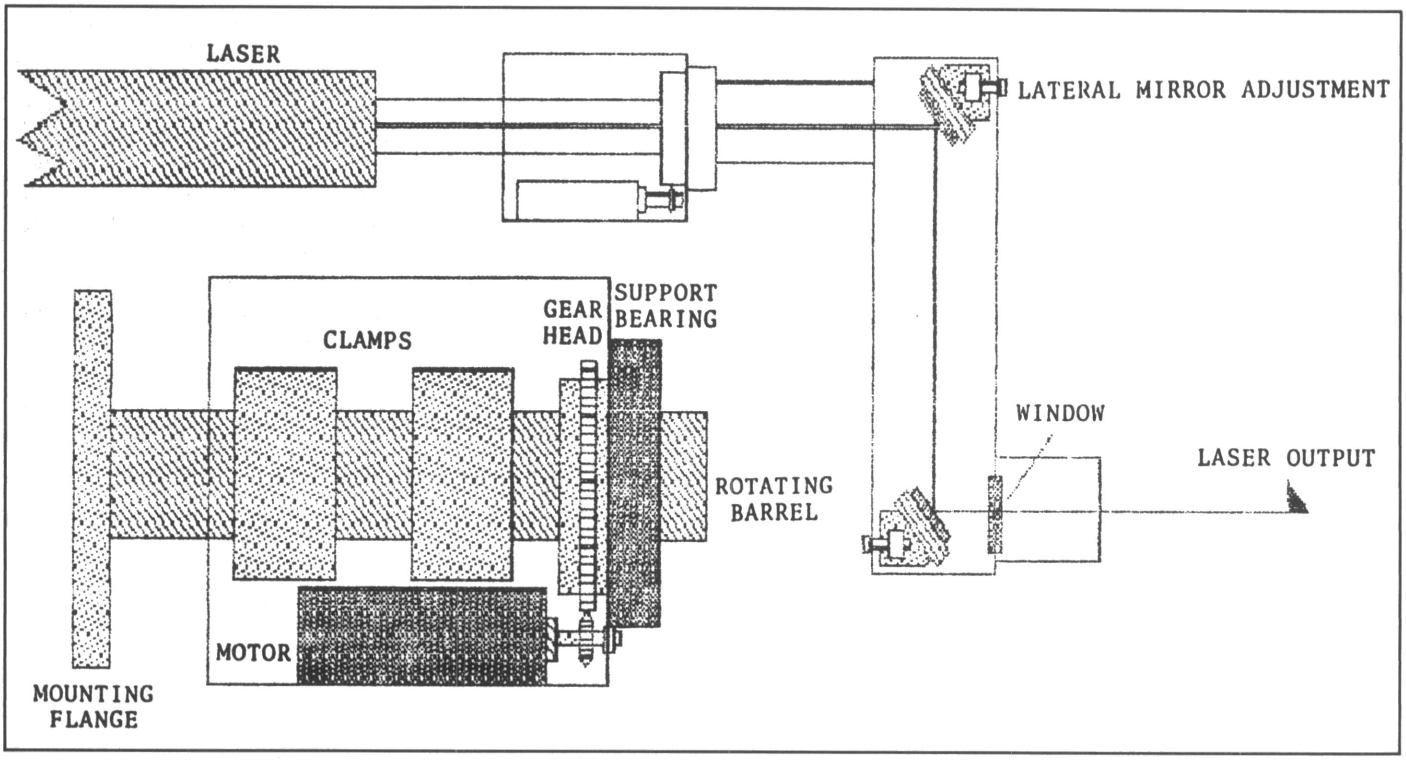


**Figure 1. The drill assembly consists mainly of an infrared carbon-dioxide laser, optics, core barrel, and scavenger pump system and is expected to weigh less than 90 kilograms.**

In any vertical ice drilling operation involving an infrared laser beam, it is necessary to remove the water from the annulus cut by the beam. This will be done by a small scavenger pump that will pick up the water at the point where it is being produced and transfer it to a holding tank at the top of the core barrel. It will be necessary to empty this holding tank each time the core barrel is withdrawn from the hole.

Figure 2 is a design for an optical system that would permit switching the laser-beam path from the position used for drilling (through beam window 1) to the position used for cutting

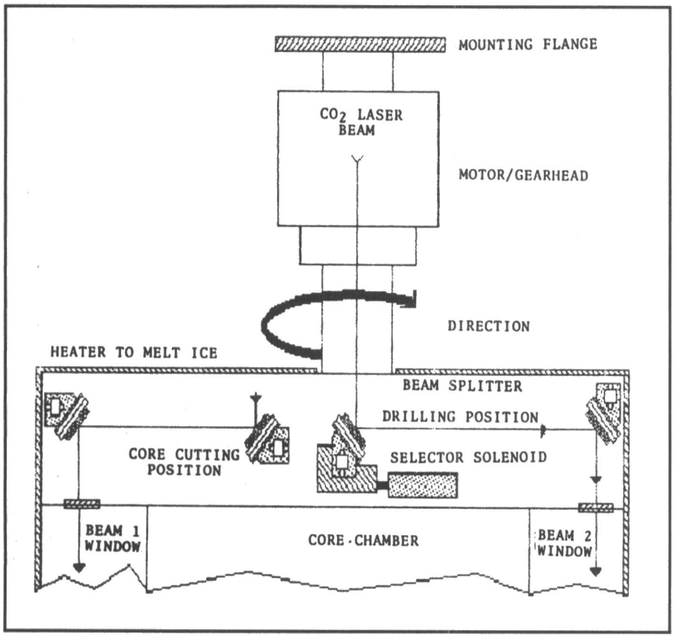


**Figure 2. Design of the optical system that would permit switching the laser beam path from the position for drilling to the position for cutting the core loose at the bottom of the drill hole. ($CO_2$ denotes carbon dioxide.)**

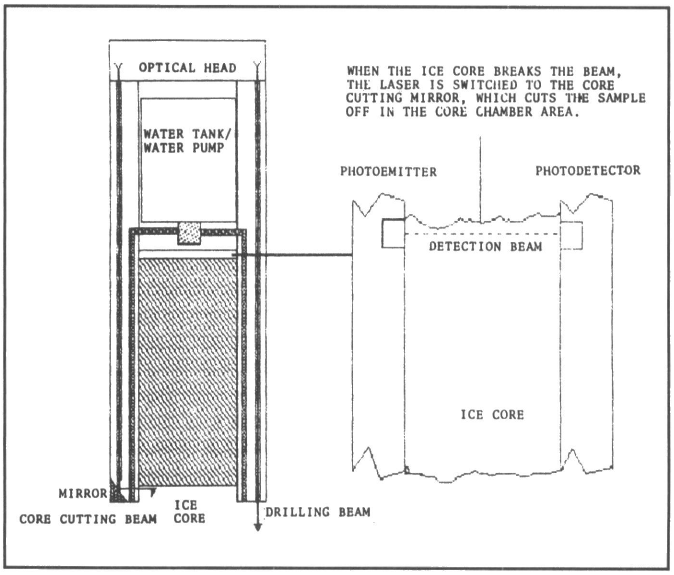


**Figure 3. The design of the core barrel includes the construction of two thin-walled concentric steel tubes. The space between the tubes will be used as the location of the wave-guide fiber and the vacuum line to the scavenger pump.**

the core loose from the bottom of the hole (through beam window 2). This would be accomplished by activating the beam selector at the center of the optical bridge. This portion of the drill assembly would be located at the top of the core barrel.

Figure 3 shows the design of the core barrel, which would be constructed of two thin-wall steel tubes arranged concentrically with the space between the tubes being used as the location of the optical wave-guide fiber and the vacuum line to the scavenger pump. In the proposed prototype drill, we will construct a core barrel to accommodate a 1.5-meter ice core segment to reduce weight and make preliminary testing easier. In a scaled-up version, the core barrel could be extended to 3 or 4 meters.

Using the laser that we already have and some of the equipment from our laboratory, we expect to produce a proof-of-concept prototype. Because of the ruggedness and high efficiency of carbon-dioxide lasers, we believe that this system could be upgraded to produce a workable drill, one that greatly reduces the logistics requirements for transport and power, for use in polar regions.

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