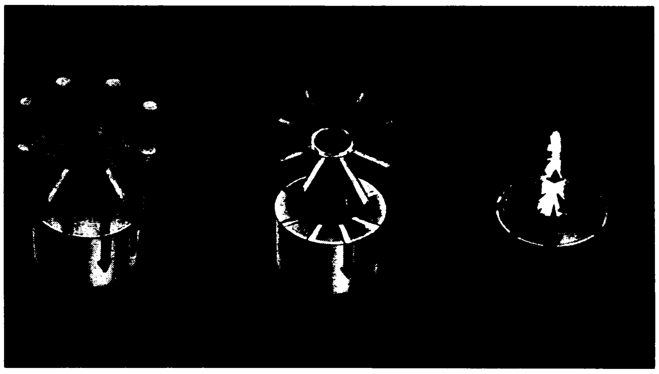
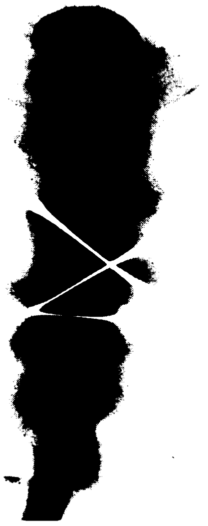
X-rays speed softly, carry a big blast





Illustrations: Sandia

Schematic above shows "gas puff z-pinch" process producing soft X-rays in modified Saturn device. First, an electric current runs through a cylindrical puff of gas, turning it into a collection of charged particles, or plasma. The current induces a magnetic field that rapidly squeezes or "implodes" the plasma. Finally, the hot, compressed plasma emits a powerful X-ray pulse. Photo at right shows plasma; bright streaks are current-carrying wires.

For defense scientists developing new X-ray generators, bigger is better. Researchers last month shot past the previous record for most powerful X-ray yield using a machine that squeezes a gas into an X-ray-emitting plasma. On its fifth try after some new modifications, the machine, called Saturn, blasted out 14 trillion watts of X-ray energy in 40 billionths of a second — expelling more than 30 times the amount of energy in all the electricity consumed in the United States at that moment.

The blast was big but "soft" — meaning most of the X-rays fell into the weaker end of the X-ray energy range. With these lower-energy rays, the researchers rely on strength in numbers to create record-breaking blasts, and they find it much easier to get a huge yield of soft X-rays than hard, explains M. Keith Matzen, who led the work at Sandia National Laboratories in Albuquerque, N.M. The Sandia scientists need both soft and hard X-rays for Saturn's major applications—weapons testing and, ultimately, the development of X-ray lasers for potential use in advanced weaponry, microscopy and holography.

Saturn in its original mode works in much the same way as a dental X-ray machine, shooting electrons at a metal sheet. The bombarding electrons reshuffle the electrons in the metal atoms, converting their energy to X-rays (SN: 10/31/87, p.276). The device can produce an X-ray dose equal to a million dental X-rays — though even the most power-crazed dentists probably couldn't fit the 96-foot-diameter cylindrical apparatus into their offices.

While the original mode yielded mainly hard X-rays, the Sandia scientists recently modified the device to work by a second process, known as "gas puff z-pinch," which generates soft X-rays. In this mode, explains Matzen, the X-rays come from a cylinder of gas about an inch long and an inch across, positioned in the center of the vast machine. To trigger X-ray production, Matzen's group must send a huge, 10-million-amp current through the gas cylinder — a task that required months of research to accomplish, he says. The current tears electrons from gas atoms, changing the gas to a sea of charged particles known as a plasma. It also generates a magnetic field that rapidly squeezes the plasma into a millimeter-thick filament. In this implosion, called a z-pinch, the plasma heats up to 10 million °C, at which point it emits X-rays.

Sandia researchers plan to use the powerful machine for blasting X-rays at various weapons to see how well they hold up. Saturn's pulses simulate the X-rays that weapons might receive from nuclear explosions in space, says James E. Powell of Sandia. Another plan, and Matzen's chief interest, is to use Saturn to develop an X-ray laser. No one yet has achieved a laser with a wavelength short enough to fall into the X-ray range, says Matzen. The shorter the wavelength of a laser, he explains, the greater the power source needed to drive it — and Saturn's soft blasts might someday provide a source potent enough to bring Sandia to that goal. — *F. Flam*

Cold traps for ion crystals, solid plasmas

Taking an electron away from an atom produces a positively charged ion. Such atomic ions repel each other. When they are cooled to temperatures near absolute zero and held in electromagnetic traps, the ions settle into distinctive patterns — from a few ions strung out like beads in a necklace to thousands of ions arranged as the surfaces of concentric shells.

Observations of such regular arrangements provide vivid demonstrations of the collective behavior of charged particles, says David J. Wineland of the National Institute of Standards and Technology in Boulder, Colo. This information helps physicists understand how charged particles interact in plasmas and other systems in which the behavior of each particle is strongly influenced by its neighbors. Recent progress in studying trapped atomic ions was the topic of Wineland's presentation last week in Baltimore at the Conference on Lasers and Electro-Optics.

Wineland and his colleagues cool singly charged mercury or beryllium ions to temperatures below 10 millikelvins, just a fraction of a degree above absolute zero. The particles sit in an electromagnetic trap that keeps them from escaping. The trap itself is about the length of the word "LIBERTY" on a penny.

The cooled, confined atomic ions move so slowly that they have insufficient energy to overcome the repulsive electrical force between them. They stay as far apart as possible and settle into patterns in which they are evenly spaced. The large spacings between ions — on the order of a few microns — allow detection of the positions of individual ions. Depending on the electric and magnetic fields shaping the trap, the researchers see these ions spread out in rings or lines.

Such orderly arrangements of trapped ions can be interpreted as crystals, clusters or even pseudomolecules. For example, Wineland and his group have studied the vibrations of a pair of trapped ions as one way of understanding the motions of atoms within a molecule, even though atoms in a molecule are much closer together. "Heating" produced by the application of an external electromagnetic field causes the structures to become disordered, or to "melt."

Assembling thousands of ions in a cold trap produces the equivalent of a one-component plasma — a collection of charged particles, all with the same mass and charge, embedded in a uniform, oppositely charged background. In this case, the ions appear to organize themselves into a number of concentric, spherical shells centered on the trap's midpoint.

Wineland and his colleagues have observed these plasmas as solids, in which the ions stay fixed in place, and as liquids, in which ions diffuse from one region to another. They have also seen a "mixed" phase in which diffusion continues within a shell but stops between shells.

Now the researchers want to increase substantially the number of particles they can hold in a trap. For very large numbers of ions, theoretical predictions suggest the shell structure should wash out and the ions settle into a type of cubic lattice. — *I. Peterson*