

interaction of atoms with a radiation field has one especially alluring application: lasing without population inversion. Such an application would contrast with the standard laser scheme, which requires more atoms in the upper state than in the lower state. The inversion is needed because the upper levels give the gain, while the lower levels cause the loss, and one naturally wants more gain than loss. Getting rid of the absorption, as in the natural Fano interferences or in the electromagnetically induced transparency schemes, should cut the loss from the lower levels. However, people tend to assume that if one cuts the absorption, the emission will be reduced as well. The idea behind lasing without inversion is that the absorption and emission profiles need not be identical. Hence one should be able to cut loss without affecting the gain.

In 1983 V.G. Arkhipkin and Yu. I. Heller (then at the L. V. Kirensky Institute of Physics, Krasnoyarsk, USSR) showed theoretically that an atomic system that exhibits a Fano interference in absorption has no such interference in emission.¹⁰ The Soviet work concerned interference between photoionization to the continuum and excitation through a discrete level. In 1989 Harris extended the analysis to the interference of two lifetime-broadened states.¹¹ Both papers discussed the application of these findings to what they called "lasing without inversion."

Olga Kocharovskaya of the Gorky Institute of Applied Physics, Russia, and her coworkers¹² and independently Marlan Scully and his colleagues from the University of New Mexico and the Max Planck Institute for Quantum Optics¹³ have followed a different route, showing how one might use the atomic coherence between a pair of ground states, as in the case of population trapping, to get lasing without inversion. They have explored several means for generating the ground state coherence, including a maser-like configuration in which coherently prepared atoms are injected into a cavity. At a meeting of the German Physical Society held in Hannover in March, Herbert Walther and Wolfgang Lange from the Max Planck Institute for Quantum Optics described a maser experiment that showed masing without inversion. They used a transition between two Rydberg states of rubidium atoms, and reported demonstrating amplification even when only the lower level was laser excited and the upper level just thermally populated.

Although no one really agrees with

the concept of lasing without inversion, most observers agree that it will be extremely difficult to build a laser based on this principle, and that the resulting laser may not even be more efficient than the ones we have today. Still, the idea is sufficiently intriguing to have attracted a number of investigators. The many theoretical papers on the subject have now begun to stimulate experimental work.

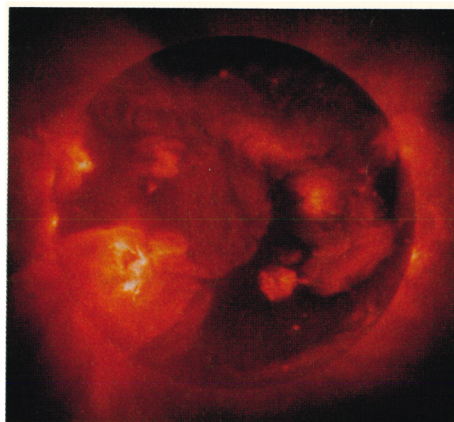
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Yohkoh Returns X-Ray Images of the Sun

The Yohkoh satellite, launched in August 1991 by the Institute of Space and Astronautical Science of Japan, has been returning high-energy solar data and images since early last fall. Designed to succeed earlier US and Japanese missions aimed at studying solar flares, Yohkoh (which means "Sunbeam" in Japanese) carries four instruments dedicated to monitoring the Sun's high-energy radiation: A soft-x-ray (0.25–4 keV) telescope,



by mapping the emission from the hot coronal plasma, records the morphology of the magnetic fields that confine and control this plasma; a hard-x-ray (15–100 keV) telescope records bremsstrahlung emission from high-energy electrons accelerated during a flare; and bent-crystal Bragg and wide-band spectrometers, which cover the spectral range from soft x rays to gamma rays, provide diagnostic data to aid in the analysis of the x-ray images.

Solar flares are thought to result from the abrupt release of free energy stored in the distorted coronal magnetic fields. Solar scientists believe that observations of the relationship between the locations of flare energy release and the structure of the solar magnetic field are central to understanding these violent explosions in the solar atmosphere.

The soft-x-ray image above was acquired on 25 October 1991. Made from a composite of three exposures of different durations to extend the dynamic range of the detectors, the image shows the detailed structure of the coronal plasma. The plasma is constrained by magnetic fields, often in the form of flux loops that are connected at both ends to the solar surface. The dark area, or "coronal hole," around the north pole (top) is a region in which the magnetic flux tubes are anchored at only one end, allowing the plasma to escape into space to become the solar wind.

The image was acquired from the Soft X-Ray Telescope, a Japan-US collaboration involving the National Astronomical Observatory of Japan, the University of Tokyo and Lockheed Palo Alto Research Laboratory.

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