Pyroelectric crystal used to drive neutron source

A team at the University of California, Los Angeles (UCLA) has developed a novel neutron source that is remarkably simple and compact [Naranjo et al., Nature (2005) 434, 1115]. The device uses the electrostatic field generated by heating a pyroelectric crystal to ionize deuterium. The ions are then accelerated toward a deuterated target, where a nuclear fusion reaction produces 2.45 MeV neutrons. Changing the temperature of a pyroelectric crystal changes its polarization. In a vacuum, this causes a charge to accumulate on the crystal surface. Brian Naranjo and colleagues gently heated a lithium tantalate crystal from 240 K to 265 K in a vacuum chamber with a small deuterium pressure of 0.7 Pa. The charge density generated on the crystal gives a potential of 100 kV. Adding a sharp W probe to the exposed crystal face produces a field at the probe tip of ~25 V nm⁻¹. This field is strong enough to ionize all the deuterium molecules that pass. When the resulting deuterium ions are accelerated and hit the target, a peak flux of 800 neutrons per second is observed. Neutron generators are already available that use an ion beam from a miniature accelerator to produce similar reactions in a solid target. Portable devices are used for well-logging in oil exploration and baggage screening in airport security, for example. However, these require high-voltage power and tend to be complex. What is really novel about the UCLA work is the use of the pyroelectric effect and field ionization to generate the ion beam, explains Michael J. Saltmarsh of Oak Ridge National Laboratory [Nature (2005) 434, 1077]. “They have developed a miniaccelerator that works just by heating it,” he told Materials Today. The UCLA researchers hope to be able to increase the neutron flux to 10⁶ s⁻¹, in particular by using a tritium target. Saltmarsh explains that this flux is comparable to other, commercially available neutron generators and that, at this intensity, “you can start to think about applications”.

Superlens breaks resolution limits in optical imaging

Researchers at the University of California, Berkeley have shown that a ‘superlens’ can beat the diffraction limit in obtaining optical images [Fang et al., Science (2005) 308, 534]. Xiang Zhang and colleagues used a thin Ag film as a superlens to record images in a photoresist with a resolution one-sixth of the illuminating wavelength. “Our work has a far-reaching impact on the development of detailed biomedical imaging, higher-density electronic circuitry, and ever-faster fiber-optic communications,” says Zhang. In 1968, Victor G. Veselago conceived of a material with both a negative permittivity and permeability that would have a negative refractive index. John Pendry of Imperial College London pointed out in 2000 that such a material could act as a superlens with no theoretical limit to its resolution. The diffraction limit arises because conventional optics can only transmit the propagating waves that emanate from an image source. The subwavelength information is contained in nonpropagating, evanescent waves that decay exponentially with distance. “The key to the superlens is its ability to significantly enhance and recover the evanescent waves that carry information at very small scales,” explains Zhang. Artificially engineered metamaterials can be generated to have a negative refractive index in the microwave and terahertz regimes. At optical wavelengths, however, no known materials have negative permeability. But in the near-field, the electric and magnetic responses of materials are decoupled, so only a negative permittivity is required. Ag and other metals have this property and surface plasmons in a metal film can enhance the evanescent waves. The team first generated patterns in a chrome mask. A 35 nm thick Ag film and a photoresist layer were then added, separated from the mask by a 40 nm thick polymer spacer layer. Illuminating the mask with ultraviolet light and developing the photoresist transferred the pattern to the resist layer. The image is recorded with sub-diffraction-limited resolution.

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