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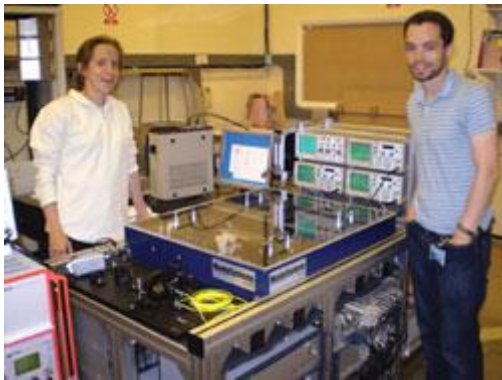
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## Synchronized flying in space makes for good detection

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TEDDINGTON, UK – Researchers from the National Physical Laboratory (NPL) are using femtosecond laser combs and optical imaging features on multiple spacecraft with the idea of creating one large detector that will enhance Earth observation and exploration of the universe.

Their theory, that formation-flying spacecrafts could gather data in a way different from a standard spacecraft, might help determine the place from which all magnetic fields originate, answer the age-old question of how the universe developed after the big bang and ascertain whether Albert Einstein's general theory of relativity is true.



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*National Physical Laboratory scientists Helen Margolis and Barney Walton stand next to their transportable femtosecond comb laser.*

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### Absolutely accurate

“Rather than trying to launch a craft hundreds of meters in size, comparable performance might be obtained by having two or more small crafts hundreds of meters apart,” said Geoffrey P. Barwood, a member of the time quantum and electromagnetics team at NPL. The method is comparable to an individual spacecraft operation because x-rays taken from a “formation flight can have the [same] resolution of a single craft that is of the size of the [overall] formation,” he said.

During formation space missions, two spacecrafts are engaged in flight with a regulation of a minimum of tens to hundreds of meters between them. The crafts operate autonomously, positioning themselves in relation to each other via femtosecond laser combs, a detector and optical imaging systems.

To establish formation, the lasers precisely measure absolute distance between crafts by emitting very short pulses of light, each lasting about 5 fs, with a repetition rate of 250 MHz and average power of 70 mW. The pulses are centered at a wavelength of 1560 nm, designed to determine distance within a few microns by enabling time-of-flight measurements.

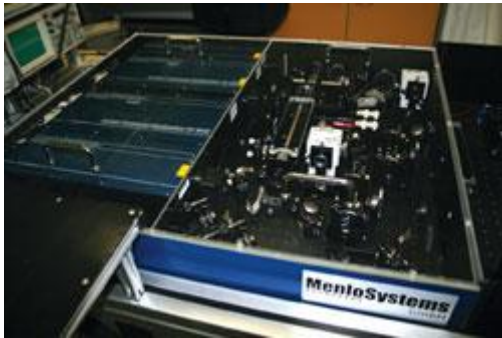
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The lasers are positioned on one craft, while a second spacecraft carries a mirror to reflect the emitted pulses back to the first craft. The time delay between the emitted and received pulses determines the distance from the known value of the speed of light, Barwood said. "This is required for the correct operation of the detectors on the spacecraft. The imaging optics and detector are on different parts of a flexible craft."

A proposed version of the technology is called the International X-ray Observatory mission, planned to launch after 2010. Barwood said that the system is not a true formation-flying mission, but that the concept is similar because the spacecraft is flexible and requires absolute distance of 300  $\mu\text{m}$  in length and an angle of 10 arcsec between the front and back of the craft to obtain clear, focused x-ray images.

Two obstacles NPL has faced with the technology are the extreme accuracy required by the femtosecond lasers, which must be strong enough to endure takeoff, and the negative effects of space, such as gravitational fields or radiation.



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*Shown is a transportable femtosecond comb laser that is used to measure the frequency of a stable laser source. The mechanism directly converts optical frequencies to low-frequency signals that can be electronically counted. Components include an erbium-doped fiber laser that produces a frequency comb operating at a range of 500 nm to 2.1  $\mu\text{m}$ , a high-stability oscillator and a GPS-disciplined Rapco 2804AR rubidium oscillator. Courtesy of National Physical Laboratory.*

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For formation-flying missions to begin, the femtosecond comb prototypes must be verified by a national standards laboratory, such as NPL. Certain specifications also must be implemented, including size, weight and power consumption, to become space-certified.

The project was funded by the European Space Agency with collaboration from Germany-based corporations Menlo Systems GmbH of Martinsried and Kayser-Threde of Munich, and from Laser Centre Vrije Universiteit Amsterdam in the Netherlands.

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