RAL DESIGN & DISCOVERY

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RUTHERFORD APPLETON LABORATORY

SCIENCE AND ENGINEERING RESEARCH COUNCIL

THE GEO PROJECT

Searching for Gravitational Waves

The observation of gravitational waves is currently one of the most challenging problems in experimental physics. The most likely sources include violent supernovae explosions, in which stars collapse to form neutron stars or black holes. Compact binary stars are also thought to emit gravitational waves as they spin together and finally coalesce.

Detection is very difficult and depends on the extremely small movements between neighbouring pieces of matter caused by the waves. The movements get larger as the separation of the pieces of matter gets larger. It seems that the best way to make a really sensitive detector is to have test masses several kilometres apart and use modern laser techniques to sense the movements between them.

Based on experience with three small prototype detectors at Glasgow University, at the Max Planck Institut fur Quantenoptik in Germany and at California Institute of Technology, several research groups around the world are planning full sized detectors of this type. Four detectors operating together as a telescope will be able to do a new kind of astronomy using gravitational waves. One of these detectors with a distance between the test masses of 3km is being proposed jointly by British and German research groups. This collaboration, called GEO, will be able to draw on RAL for skills in project management and large-scale engineering. Key technologies include high vacuum, very efficient vibration isolation, high power lasers, and control engineering.

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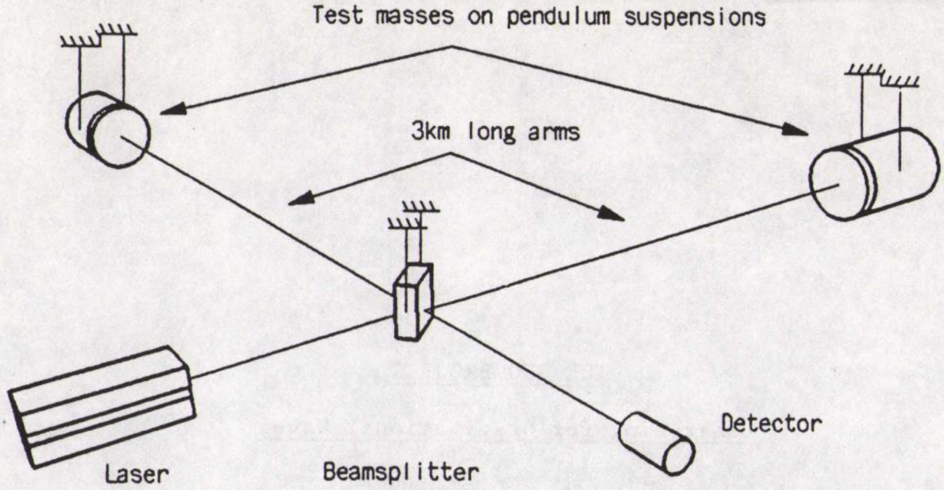
How the detectors work



Two arms at right angles to each other are formed between masses hung as pendulums. The pendulum suspension provides the final stage of a system to isolate the masses from unwanted vibrations. Light from a laser is split into two parts and fed to the two arms where it is reflected back and forth between the test masses many times before emerging. This arrangement multiplies the effects of tiny movements of the masses. The movements of the masses cause changes in the phase of the emerging light. These phase changes can be seen by adding together ('interfering') the two emerging light beams. Various sophistications are needed to allow even this very sensitive method to detect the exceedingly small movements involved. For example, the entire system must operate in a high quality vacuum and very powerful lasers are needed.

Parameters of the GEO detector

Gravitational wave sensitivity, millisecond pulses:
$h=10^{21}$, improving to $h=10^{22}$

Detector type: Initially retro delay lines in arms, adding Fabry-Perot later.

Length of arms: 3km.

Vacuum system: approx $6000m^3$ of vacuum at $\sim 10^{8}$ mbar total pressure.

Lasers: Up to 100W of cw Nd-YAG laser power.

Isolation of test masses from ground-borne vibrations: $\sim 10^{12}$ at 100 Hz.