Quantum Accelerometer

(A giant leap in navigational system)

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ABSTRACT:

Quantum accelerometer is a device which will make navigational systems more accurate in locating the objects. It works on the theory of quantum positioning which is being discussed in this paper briefly. Nowadays, GPS system is most popular system in the world for navigational purpose. But if GPS system fails, then devices still relies on accelerometer measurements. These accelerometers do not provide accurate results rather they provide result on the basis of last known position. So, to make these accelerometers' results upto 1000 times accurate, quantum accelerometer is developed. Even thoug this device is still to be tested for submarines' navigational .purpose but if the size and power of this device is minimized, then in future this device will have a great impact on navigational system.

Keywords:

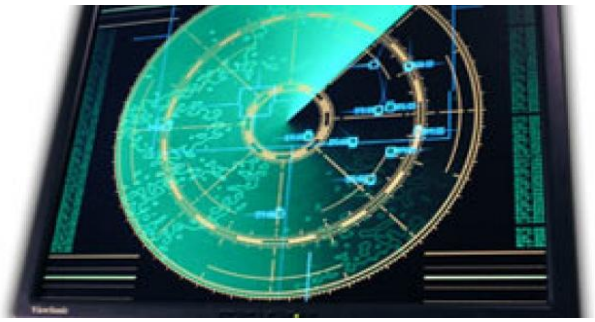
quantum positioning; Doppler cooling; INS; gravitational anomalies; dead reckoning position

INTRODUCTION:

In earlier times, people used star constellations and compasses to navigate their ways through some forests or sea or through some unknown places. As time passed, the technology developed and things started getting modernized. Many researchers and scientists worked together to develop a navigation and positioning system called GPS (Global Positioning System). It works with the help of GPS satellites and GPS receivers. The GPS satellites continuously transmit the data based on the time and position of the satellite with respect to the object. From this data the position of the object can be calculated. This system is still known to be the best of all navigational systems. But nowadays, we take GPS so much for granted on land that it's easy to forget where GPS doesn't work. It has some disadvantages like it do not actually work in some areas as in deep sea levels where there are strange sea creatures and submarines roam around. Submarine navigation today still relies on accelerometers (if GPS fails), which records its movements from a last known position. But accelerometer also was not found to be very accurate in certain conditions. Then, the concept of QUANTUM POSITIONING came to

existence. By using this technique, accelerometer can be designed to give results with up to 1000 times accuracy than presently existing systems. In the coming times, this technology will prove to be a great success in navigational field. In the coming sections of this research paper, the working principle, structure, applications and drawbacks of quantum positioning will be discussed.

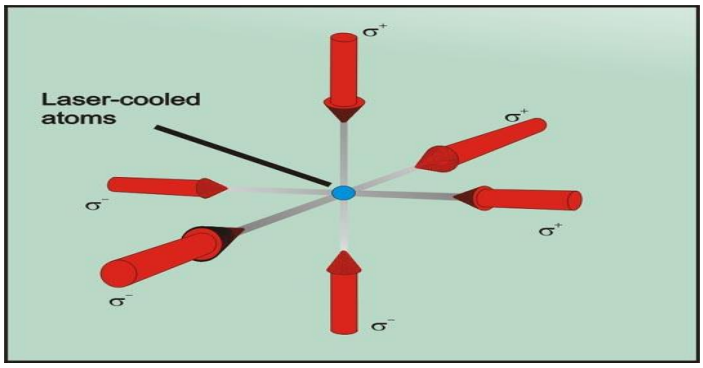
WHAT IS QUANTUM POSITIONING?



"Quantum positioning works on the Nobel prize winning discovery that lasers can be used to trap and cool a cloud of atoms(to a fraction of degrees above absolute zero temperature) in a vacuum. Once it is cooled, the cloud of atoms can be easily perturbed (disturbed) by an external force. Then another laser beam can be used to track the changes caused by the perturbation and these changes can be used to find the outside force."

In the year 1997 or so, some scientists discovered that if we can trap a cloud of atoms in a vacuum by using lasers, then that cloud can be cooled down to a temperature slightly above absolute zero temperature. While working on this theory, in 2014, a group of researchers found that a frosty atom can get easily disturbed by an external force. If we point another laser to the cloud of atoms, then we will be able to track the atoms and their locations based on the force of their movements. The location tracked by this could be 1000 times more accurate than current accelerometers.

QUANTUM ACCELEROMETER:



The quantum accelerometer is the device used to implement the practical use of this theory. It is a instrument having a size of shoe box (which will be made smaller in future), inside the box is a vacuum having a cloud of atoms trapped inside. This box is can be put in any moving object. When a laser strikes on the cloud, the cloud gets cooled (as defined by theory). Then with movement of the object, the cloud of atoms will move and another laser can be used to track the motion. By this, not only the position but the direction of motion of the object will also be known to us.

This device is yet to be tested and it will be tested for submarines first. The device will make it a lot easier for submarines to pinpoint their position underwater to within 1m after travelling one day, when they are unable to use GPS. This is much better than the possible scenario with current accelerometers, which are accurate to within 1 km after a day's travel. With further development, the device could be used for oil exploration or even to do "gravity scans" of concealed objects.

Since the 1990s, physicists have been able to do interferometer experiments with ultra cold atoms. Under the guidance of a professor in Stanford University 'Mark Kasevich', the main version of the experiment was to make an atom fall under the influence of the Earth's gravity. Then a laser pulse is fired at that atom that puts it in a superposition of two quantum states, allowing it to follow different trajectories (as photons travel through an optical interferometer). Then a second pulse is fired which recombines the states and the resulting interference is used to measure of gravity – and also used to reveal subtle effects of the general theory of relativity.

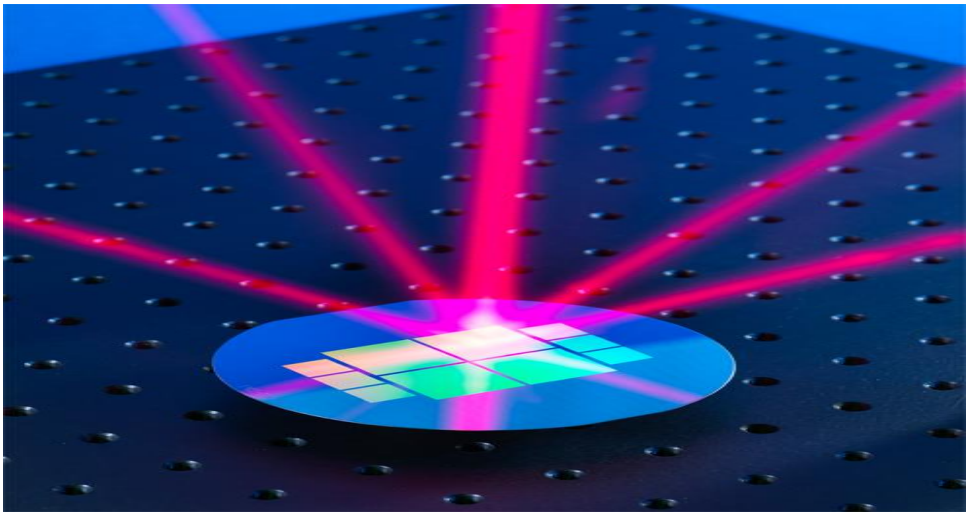


Fig.: An Illustration showing how a single laser beam is converted into four beams after diffracting from a patterned surface. These beams are then used to trap ultra cold atoms in the new accelerometer.

Such a device can also be used as an **extremely sensitive** vertical accelerometer. Researcher Ed Hinds and colleagues at Imperial College London have done this experiment. They rotated it by 90° to make an accelerometer that works in the horizontally. It uses about one million rubidium atoms, which are trapped on an integrated chip using a magnetic field and laser light.

An important feature of the chip is that a single beam of laser light is used to trap the atoms. This beam is fired at a surface grating to create several beams of diffracted light, which together with a magnetic field are then used to trap the atoms.

HOW TO GET ULTRA COLD ATOMS?

We need to use the "momentum conservation" theory in order to get ultra cold atoms. When an atom moves toward a laser beam, it absorbs the photon from the incoming laser beam

Photon. After that, the atom's momentum will be reduced to maintain the conservation of the momentum. The most useful technique to get ultra cold atoms is called Doppler cooling. It uses a method in which laser beams are set up along x, y and z axis to impart the momentum from all directions. This limitation of three degrees of freedom reduces the particles' kinetic energy resulting in cooling of the atoms. If sufficiently low temperatures are

reached, the atoms form a new state of matter that is governed by quantum mechanics.

How it is more efficient than normal accelerometer?

To know about how it is more efficient than normal accelerometer, we should first discuss about how an accelerometer works. Basically it is a part of INS (inertial navigation system). It is explained briefly as:

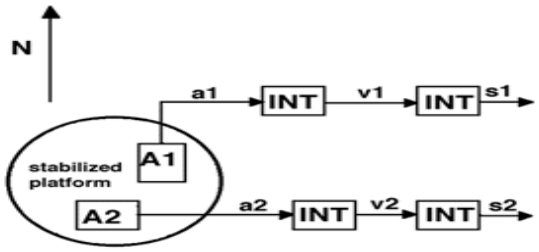
Inertial Navigation System

Inertial Navigation System (INS) is basically used for submarines. It is a passive and autonomous navigational system. It determines dead reckoning position by double integration of measured acceleration.

The INS has following parts or components:

- stabilized platform,
- accelerometers
- integrators and
- Computer.

It also has a elimination unit, which eliminates the accelerations not included in real movement of device but measured by accelerometer. Stabilized platform keeps track of precisely horizontal position and correct orientation of accelerometers by using gyroscopes.



A1 - accelerometer in direction of axis North-South
A2 - accelerometer in direction of axis East-West
a1 - acceleration in direction of axis North-South
a2 - acceleration in direction of axis East-West
v1 - velocity in direction of axis North-South
v2 - velocity in direction of axis East-West
s1 - travelled distance in direction of axis North-South
s2 - travelled distance in direction of axis East-West
INT - integrator

Accelerometers measures acceleration of an object in particular direction (named measuring axis of accelerometer). A measuring sensor is placed inside it. Mainly, a sensor mass is put into a liquid which is placed inside the cylinder of accelerometer. For an object moving in two dimensions, only two accelerometers can be used. Since a submarine moves in all three dimensional axes, so three accelerometers are needed for its navigation. If there is any change in velocity (acceleration) of submarine, then the position of measuring sensor inside the accelerometer changes with it. The change is recorded and sent to the integrators which integrate the velocity changes and provide the distance travelled. Then the entire data is being sent to computers which compute the geographical position of the submarine. But errors in the INS calculations increases by time and because of that, it is not fully autonomous during longer period of time.

The main issue is that submarine navigation today still relies on accelerometer calculations, which records a sub's movements from its last known position. The longer the sub roams without surfacing for a GPS "fix" on its position, the less accurate the path plotted by its accelerometers. A day without a

GPS fix can take a sub a kilometer off course. This drift of a kilometer in submarine's position is a big issue in locating them underwater.

Quantum accelerometer can become a solution to this problem. This device can reduce the drift of the submarine up to only a meter or so. So it gives 1000 times more efficient result as compared to previous accelerometers.

Factors affecting performance:

This quantum accelerometer will surely be very useful in the future but also it is not a done deal yet because one factor that will need to be taken care of is its exquisite sensitivity. Even tiny amount of the gravitational anomalies (caused by undersea mountains) could confuse the accelerometer and the accelerometer can't distinguish between tiny gravitational effects and accelerations caused by a vessel's movement. Thus, if any submarines pass through an underwater mountain whose gravity tends to attract it to west that will be observed by the accelerometer like acceleration to the east. This implies that in order to make this instrument work more accurately, very good gravity maps will be required.

FUTURE MODIFICATIONS:

Many researchers think that this device and technology will have the greatest impact in future. It will make submarines go easier It will also be used in modern warfare system when it has shrunk down in size as maybe a submarine need not provide its positions accurate to meters and centimeters but a missile or shell might require this.

But this technology has applications beyond warfare also. In future, this technology may be available to use in vehicles, planes and in cell phones to track them where GPS signals are blocked. It's a convincing fact that if the size and power of this device comes down, it will be available for a broad use in future.

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