Crucial Tests of the Special Theory of Relativity

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The most accurate "aether drift test" ever conducted was done in 1968 at the Univ. of Birmingham, UK, by Prof. George Isaak and this author.[1] Involving Moessbauer gamma rays, the test directly measured the one way speed of light at all azimuthal angles, and set a limit of 1.5 cm/sec limit on any propagation anisotropies. Unlike all optical experiments, which measure changes in light speed via secondary interference effects, the afore-mentioned test measured changes in light speed as a primary quantity by determining the propagating speed of the gamma rays between the Moessbauer source and the absorber, both mounted to a high speed rotor. Repeated at seven different times in the solar cycle and typically lasting 2-4 days around the clock, the test was so sensitive that it even ruled out secondary effects (in v/c), as might be caused by non-uniformities in the mass-velocity distribution of the surroundings. Of course, the null effect is predicted by "emission theory", which states that light is emitted from its source with velocity c+v, where "v" is the velocity of the source.

Inspired by Kantor's claims[2] to have measured effects validating emission theory, in 1986 Fritz K. Preikschat and this author set out to test emission theory using a high speed (corner cube) mirror in a high vacuum (to eliminate extinction effects as predicted by Ewald-Oseen's extinction theorem). This optical test used a He-Ne laser, pulsed in synchronism with the speed of rotation of the mirror. The reflected return beam was split into two parts, both going the full length of an evacuated 30′ length of a drift tube, and continuing through separate, stationary glass slides, one located at the entrance to, the other at the exit of, the drift tube. The wave fronts of the two parts were then compared in an interferometer. The test was inconclusive because the rotor was not stable enough to allow longer term measurements.

At this stage, it appears that no laboratory test performed in high vacuum has yet exclusively tested the effects of light emitted from a high speed source. The author will suggest potential avenues for future test work.

1. Introduction

In 1887 Michelson & Morley, in the famous experiment bearing their name (MMX),[3] measured the round trip speed of light at orthogonal angles in the horizontal plane and determined the speed to be constant to better than 10 km/sec. This test ruled out the existence of the classical "aether drift", which was expected to be 30 km/sec, the velocity of the earth around the sun. The Special Theory of Relativity (STR) was conceived by Einstein in 1905 to explain the MMX null result, by postulating that "all inertial frames of reference are equivalent and that light is a universal constant "c" which is independent of the velocity of the source or the observer."

Since the first MMX, numerous attempts have been made by others to improve on the measuring accuracy of the original MMX, see Fig. 1.

A very substantial increase in accuracy was achieved when methods became available that are sensitive to the 2nd order in v/c. The first such experiment was conducted by Cedarholm, et al[4] in 1958 using two ammonium beam masers and set a limit of 30 m/sec.

With the event of the Moessbauer effect and its high inherent measuring stability, it was possible to gain several orders of magnitude improvement in accuracy. At the Univ. of Birmingham, several groups were actively involved in these measurements. The first was Champeney and Moon[5] (1961) who set a limit of 10 m/sec, Champeney and Isaak[6] (1963) set a limit of 3 m/sec, and the last and most sensitive experiment was conducted by the above author as part of his Ph.D thesis[1] in 1968. The work was supervised and co-authored by Prof. George Isaak, who later gained international renown for his discovery of solar oscillations. The work was sponsored by the UK Royal Society, the world's oldest scientific academy, founded in 1660.

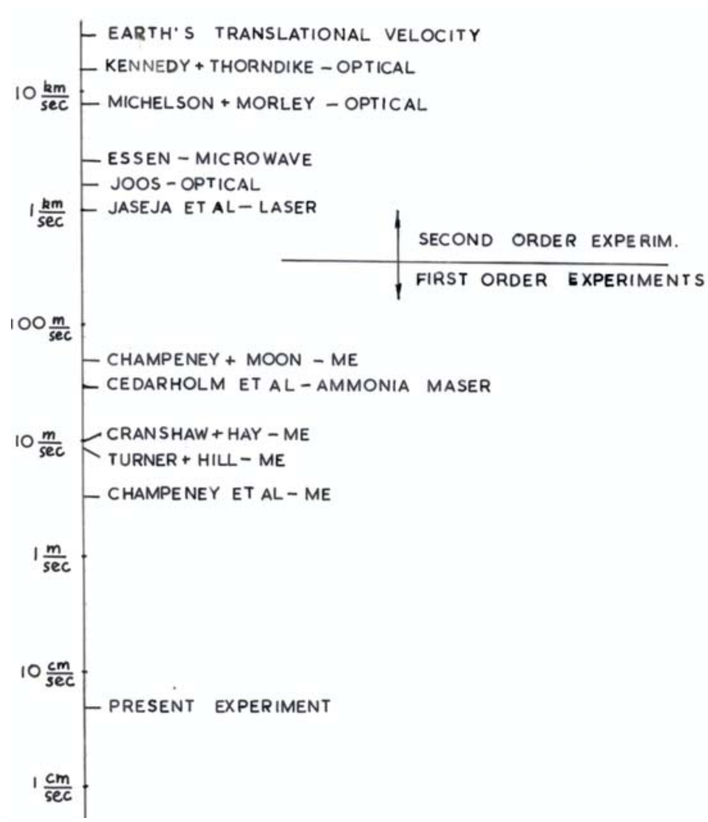

Fig. 1. Experiments Testing "Aether Drift" (Fig. 6.22 of [1])

2. Description of the Moessbauer Experiment

The Moessbauer Effect, and in particular the Fe^{57} 14.4keV gamma ray resonance, has a sensitivity of one part in 10^{12}, one of the most sensitive resonance lines in existence. Fig. 2 shows the complexity of the apparatus.

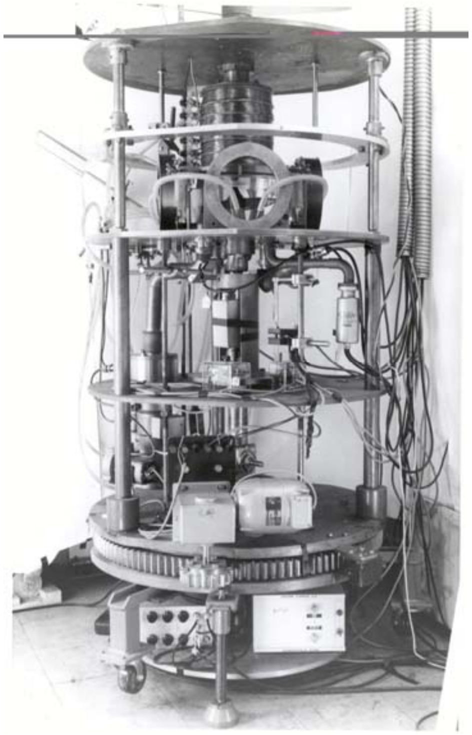

Fig. 2. Text? (Plate 5.1 of [1])

Gamma rays are given off during nuclear decay. Whenever a gamma ray is emitted from the nucleus, the nucleus recoils causing a loss of energy in the gamma ray. In the case of the Moessbauer effect, the recoil of the nucleus is taken up by the whole crystal lattice, which has infinite mass, and hence negligible recoil. Hence both the emission and absorption of the gamma rays occurs without loss of energy. One can shift the whole absorption curve across this resonance by effectively Doppler-shifting either the source (or the absorber) by a velocity as small as 0.3 mm/sec.

This particular resonance was previously used by Pound & Rebka[7] to show that light is affected by gravity. They mounted a Fe^{57} source at the top of a tower, and the corresponding absorber at the bottom, and showed that the gamma rays were blue-shifted (or red-shifted) when they were "falling down" (or "going up") the tower.

Using Moessbauer gamma rays is of particular interest, because, by comparing the two clocks of the source and the absorber, one is able to directly measure the one way speed of propagation of the gamma rays. The speed of propagation of light "c" is equal to the product of the wavelength "λ" times its frequency "υ".

$$c = \lambda \upsilon$$

When, in a Moessbauer experiment, the distance between source and absorber is held fixed, then the wavelength □ is fixed, and light speed is directly measured by comparing the "nuclear clock frequency" of the source with that of the absorber. A change in the light speed would show up as a change in the frequency or energy level of the gamma ray, which would shift the counting rate up or down the absorption curve.

This is in contrast to all the optical experiments, where light speed is only measured as a secondary quantity, by comparing the round-trip speed of light as a fringe shift in an interference pattern between two light beams going separate paths.

In our 1968 experiment the Moessbauer source was mounted at the rim of a high speed rotor and the absorber inside a Beryllium skirt near the center of the rotor, with a proportio-nal counter stationary at the center of the skirt to detect the gamma rays – see Fig.3.

Fig. 3. Rotor with Steel Skirt and Optics (Plate 5.3 of [1])

The rotor was magnetically levitated inside a vacuum chamber and accelerated by a rotating magnetic field until it reached a tip speed of about 1.5 km/sec, equivalent to 5 times the speed of sound.

In essence we used Pound & Rebka's gravitational red-shift to shift the Moessbauer absorption line to the steepest part of the curve. It took about 12 hours to reach operating speed, which was then maintained for a continuous period of 2-4 days. The test was repeated 7 times at various times of the earth's orbit around the sun.

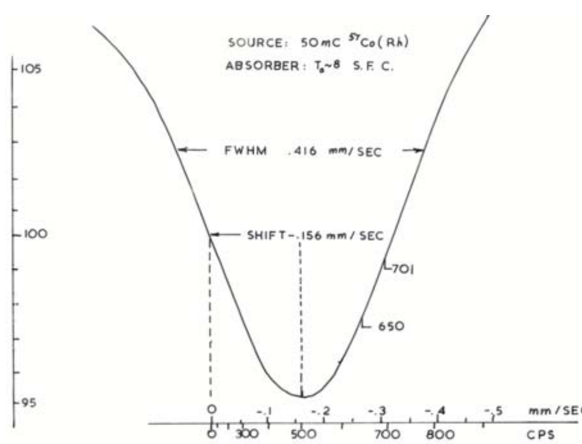

Fig. 4. Text? (Fig. 6.4 of [1])

Fig. 4 (Fig. 6.4) shows the absorption line, as a counting rate on the Y-axis, and as a function of the rotor speed, on the X-axis. It shows that at a rotor speed of 500 cps, the absorption line is at a minimum (with zero slope), and reaches maximum sensitivity at a rotor speed of 700 cps. We monitored the counting rate around the clock by counting the number of gamma rays as a function of azimuthal angle. The counts were collected by a 16 channel multi-channel analyzer, each channel representing 22.5^{o} of azimuthal angle, and recorded every 90 minutes. At the end of the day we had 16 sets of 16 channel data, which were displayed in a 16 x 16 matrix. By shifting each successive data set by one channel, we corrected for the daily rotation of the earth, so that the data was, in essence, collected in a stationary - relative to the universe - frame of reference. We summed the data columns and then analyzed them for diurnal variations.

In total 60 run series were taken throughout the year, each series lasting a day. Major run series were collected in July, August, October, April, May, November, February, March. We summarized all data and reduced them to one number. We did not see any "aether drift" and were able to put an upper limit on our measuring accuracy of 1.5 cm/sec.

This limit is about six orders of magnitude smaller than that due to the motion of the earth around the sun. The test was so sensitive that it even ruled out the existence of second order effects (in v/c) as might be caused by non-uniformities in the mass-velocity distribution of the surrounding universe.

In order to establish the true local rest frame in the cosmological sense one would not only have to know the mass-velocity distribution of the universe but also the detailed interaction between local and distant matter. One approach to the latter problem is given by the theory of Sciama[8] (1953). According to this theory the contribution of matter to local inertia falls off with the inverse of the distance, so that the relative contribution of the earth, sun and our galaxy to local inertia are 10^{-9}, 10^{-8} and 10^{-7} respectively, which is negligible compared to the contribution of the universe as a whole.

The null effect is predicted, of course, by the “emission theory”, which states that light is emitted from its source with velocity c+v, where “v” is the relative speed of the source relative to the absorber, in our case zero. Some time ago, Fox[9] (1962, 1965) suggested that the emission theory of light had not been as thoroughly disproven as had generally been thought. Prior to 1962, the main evidence came from the observation of binary stars, but as Fox pointed out, this evidence was not conclusive as the effect of the extinction and reemission of light caused by interstellar matter had not been considered. According to Ewald & Oseen primary radiation (of wavelength λ) propagating through a medium with index of refraction n, is extinguished in a distance of "d", where $d = \lambda/2\pi(n-1)$, and is replaced by secondary radiation (of same frequency but different propagating velocity), which is emitted by the forced oscillations of the radiating dipoles in the medium.

Experiments designed to test the emission hypothesis must thus be entirely free of extinction effects in order to give a conclusive result. Kantor[2] (1962) performed the first optical experiment in which this condition was met and claimed to have obtained a result which was consistent with the emission theory. Later experiments, however, conducted by Babcock and Bergman[10] (1964) and by Beckman and Mandice[11] (1964) contradicted Kantor.

3. Description of the Kerr Cell Experiment

In 1986, Fritz K. Preikschat and the present author conducted a new optical experiment, as shown in Fig. 5, to test the validity of the emission theory. It used a high speed rotor to spin a corner cube reflector to reflect a pulsed laser light beam back down the path of a 30' length of drift tube, all maintained at a high vacuum of 10^{-6} Torr.

Fig. 5.

The light output from a He-Ne laser was pulsed by a high speed Kerr cell in synchronism with the spinning corner cube reflector. When the corner cube reflector was in place to reflect the light beam, the Kerr cell was activated to allow the light beam to go down the full length of the 30' long drift tube. The light was then reflected and sent down the reverse path of the same drift tube.

The reflected light was split into two halves, each going through separate thin glass slides, one positioned at the entrance of the drift tube, the other at the exit, see Fig.6.

Fig. 6.

In accordance with the emission theory, the light reflected by the corner cube was propagating at speed of c+v, where "v" is the velocity of the mirror. The afore-mentioned extinction theorem would cause the light, going through a glass slide, to be extinguished and to be re-emitted with new velocity "c".

Hence, the light going through the first glass slide would be propagating at speed "c", while the 2nd - not yet extinguished half of the beam - would continue to propagate at speed "c+v". Then, when the two halves of the beam were recombined in an interferometer, the emission theory would predict a fringe shift between the two wave-fronts, while the STR would not.

This optical experiment was very complicated: it required the light to be pulsed and to traverse, back and forth, the 30' length of beam tube. For this to work, it required very high rotor stability, which, unfortunately, was never achieved, and as a consequence we were never able to obtain a clear, conclusive result.

Conclusion

As of this day, in the opinion of this author, nobody has as yet conducted a definitive experiment to disprove the validity of the emission theory. It would appear that the demands of conducting a high speed experiment at high vacuum are very difficult to achieve in an earth bound laboratory.

However, these conditions are readily met in a satellite based experiment using two observers in opposite orbits. One observer carries a large corner cube reflector. The other observer shines a laser beam at the corner cube reflector. Then, again splitting the beam and using a 2 glass slide set-up as shown in Fig. 6, one compares the two halves of the wavefront, and, if the emission theory holds, any fringe shift seen is a direct measure of the speed difference between the two observers.

My father was so sure of the validity of the emission theory[12], that he tried to patent this "space speedometer" only to be told that the validity of STR had not yet been overturned.

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