Hidden energy in the destructive interference

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Two simple experiments and a simulation show that energy can be hidden in invisible and immeasurable beams.

I. Introduction

The superposition of two coherent light beams of the same intensity, which are 180° out of phase with each other, leads to complete destructive interference. In this case, the electric and magnetic fields of the two beams cancel out each other, causing invisibility and immeasurability of the resulting beam, its photons and its energy.

Simple measurements show that destructive interference absorbs energy. Since superposition does not change this energy, it must hide in destructive interference. The law of conservation of energy is not violated just because we cannot measure the hidden energy directly.

As soon as the destructive interference collapses, the two beams and its hidden energy become visible and measurable again.

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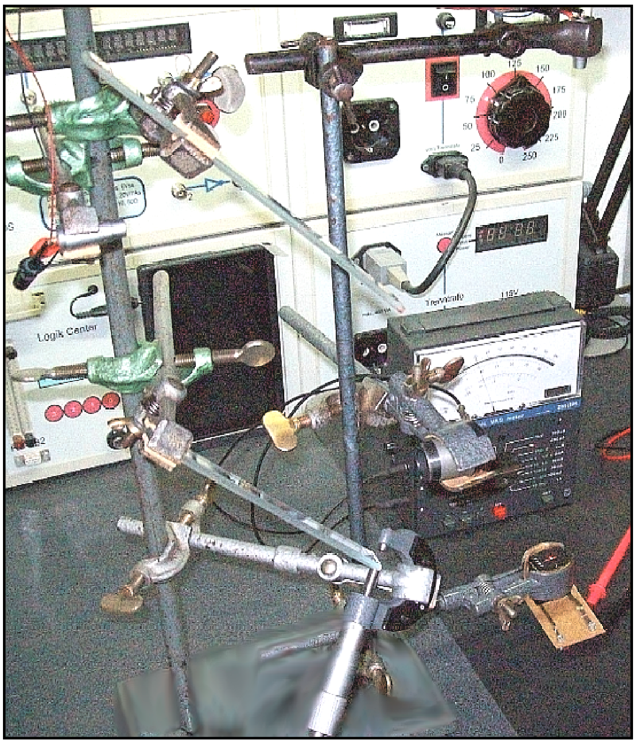
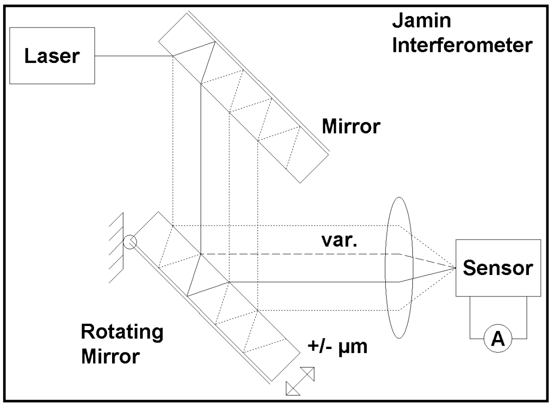
II. Experiment: Interferometer

A Jamin interferometer generates several parallel output beams from one laser beam with two normal mirrors. Some beams are adjustable between destructive and constructive interference by rotating one mirror with a micrometer screw. Usualy only the "var." beam is used. Since energy measurement is involved here, all input and all output beams must be measured.



Interferometer (with double slit experiment at right)

Principle of the experiment



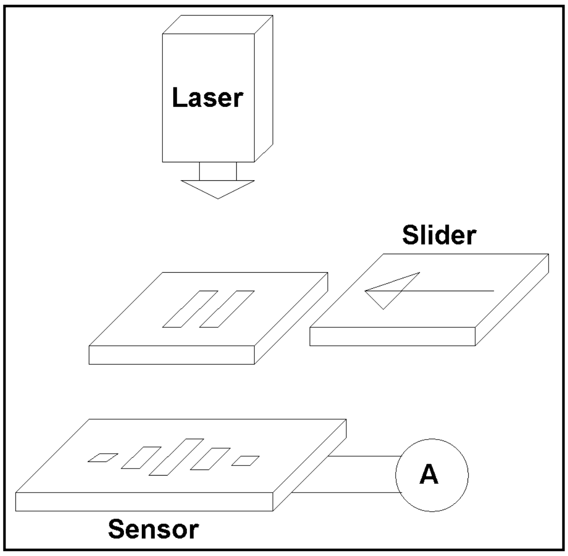
Photodiodes, photoresistors, photoelements and a photomultiplier were used, some with optics to achieve the required large apertures. All sensors showed similar tendencies with respect to the light energy.

The laser power (P_{laser}) and the losses (P_{loss}) due mirrors and scattered light were constant. In contrast, the intensity of all simultaneously summed output beams ($P_{visible}$) was variable. Max. constructive interference generated a sensor signal of e.g. 500 µA ($P_{visible} = P_{laser} - P_{loss}$), which decreased to e.g. 420 µA ($P_{visible} < P_{laser} - P_{loss}$) at max. destructive interference.

Since the input energy and losses are constant and the measurable output energy is reduced with destructive interference, it is evident that some of the energy has been hidden in the invisible output beam.

III. To validate the interferometer experiment, a double slit experiment is performed

Often to read is the opinion that when two slits are opened the intensity doubles and from this the interference pattern arises by redistribution. This is incorrect, as the following experiment shows.



Principle of the experiment

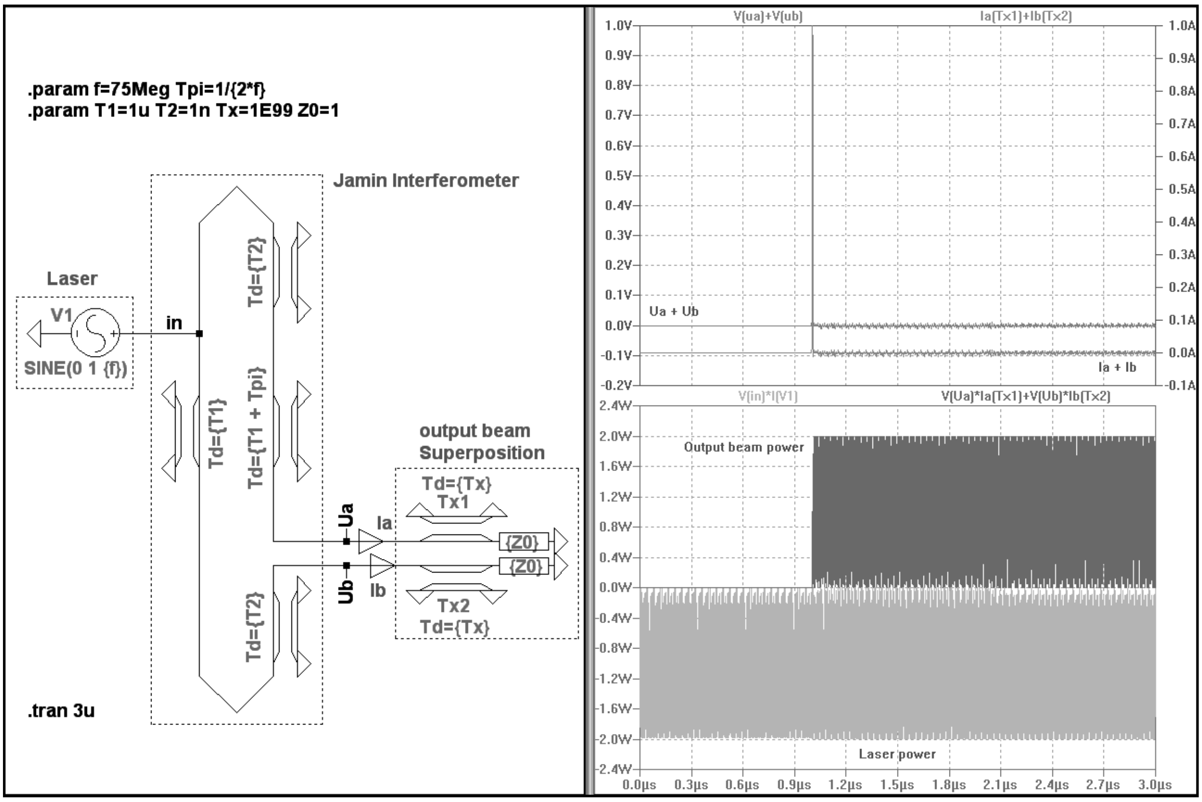
The setup is simple: laser, double slit and sensor with large aperture to capture the diffraction pattern as a sum value. But the handling is difficult, because covering a slit in a dark room requires skill. Furthermore, the sensor signal must be linear to the light intensity.

First, one slit was covered and the output intensity was measured (9 µA). Then the other slit was covered and both intensities were mathematically added (9 + 8 = 17 µA). Then both slits were opened and only 13 µA was measured. So 4 uA are missing.

The double slit also gives the same result as the Jamin interferometer. As soon as destructive interferences occur, a part of the energy has been hidden in the destructive interferences.

IV. To validate the interferometer experiment, a simulation is performed

The f=75MHz-"laser beam" enters the input and splits. Z_0=1Ω-lossless transmission lines are used to simulate the light travel times. Symmetrical reflections are rudimentary simulated with T_2. The left beam run within T_1 vertically through the interferometer. The right beam is extended by the rotating mirror so that a path difference of 180° (T_{pi}=1/(2f)) occurs. Both partial beams superpose (= galvanically separated) in the long $T_x=10^{99}$s-“output beam“.



The plots shows voltage and current at the feed points of the output lines and the constant output power of the laser and the absorbed power of the output beam. Up to T_1+T_2 the laser energy is stored in the interferometer. Further energy is absorbed by the output beam, although it is not visible or measurable. This simulation leads to two simple formulas:

$$\mathbf{P_{visible} = (U_a + U_b)^2 / (2\,Z_0) = 0} \qquad \mathbf{(1)}$$

The E- and M-fields cancel out by destructive interference. The output beam is invisible.

$$\mathbf{P_{beam} = (U_a^2/ Z_0) + (U_b^2/ Z_0) = P_{laser} = P_{visible} + P_{hidden}} \qquad \mathbf{(2)}$$

The power of the output beam is independent of the interference.

V. Discussion

The power of the output beam (2) is constant and consists of visible and hidden parts. The visible energy (1) is subject to interference. It is quite interesting, that these findings are similar to Feynman's formulas [1]:

Feynman's probability with interference:	$\mathbf{P_{12} = \|\phi_1 + \phi_2\|^2}$
Power with interference, derived from (1):	$\mathbf{P \sim (U_a + U_b)^2}$
Feynman's probability without interference:	$\mathbf{P_{12} = \|\phi_1\|^2 + \|\phi_2\|^2}$
Power without interference, derived from (2):	$\mathbf{P \sim (U_a)^2 + (U_b)^2}$

Destructively interfering light consists of normal light and therefore carries energy. However, this energy escapes direct observation or measurement in destructive interference. When destructive interference occurs, measurable energy is missing, because this energy is hidden in the invisible and unmeasurable superpositions.

The law of conservation of energy is not violated by this. We just do not have senses and sensors to detect destructive interfering light directly.

According to the superposition principle, photons do not notice their transient destructive interference. Only the baryonic environment can notice it, with which the destructively interfering light does not interact in the usual way.

As soon as the destructive interference ends, the light is visible and measurable again, as if nothing had happened.

[1] Feynman, Leighton, Sands, The Feynman Lectures on Physics, Vol. III, Addison Wesley Publishing Company