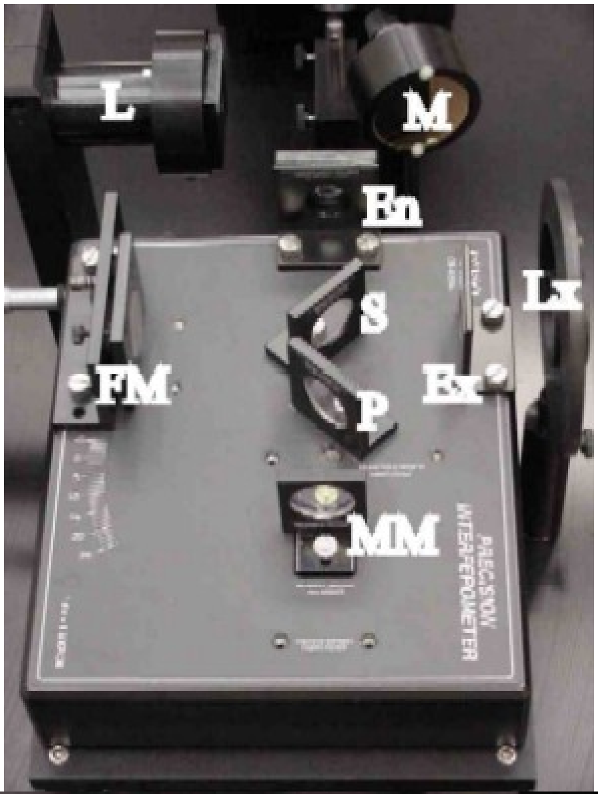
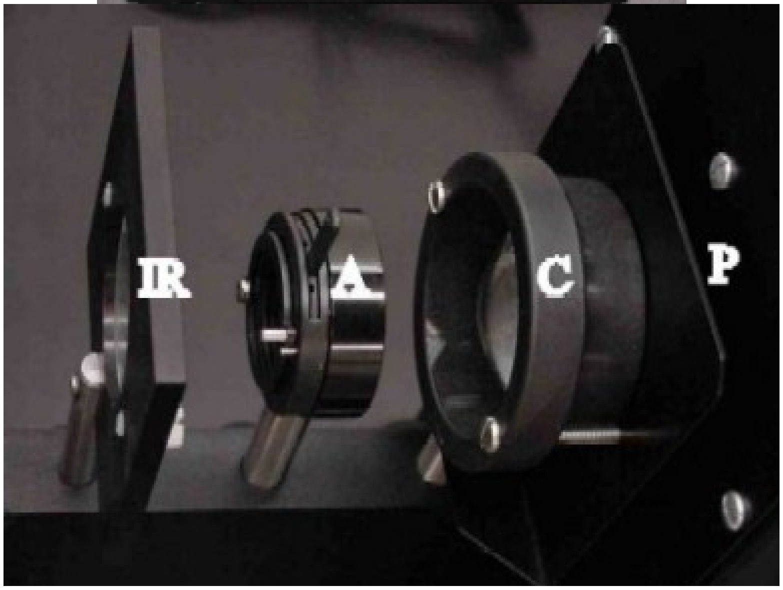
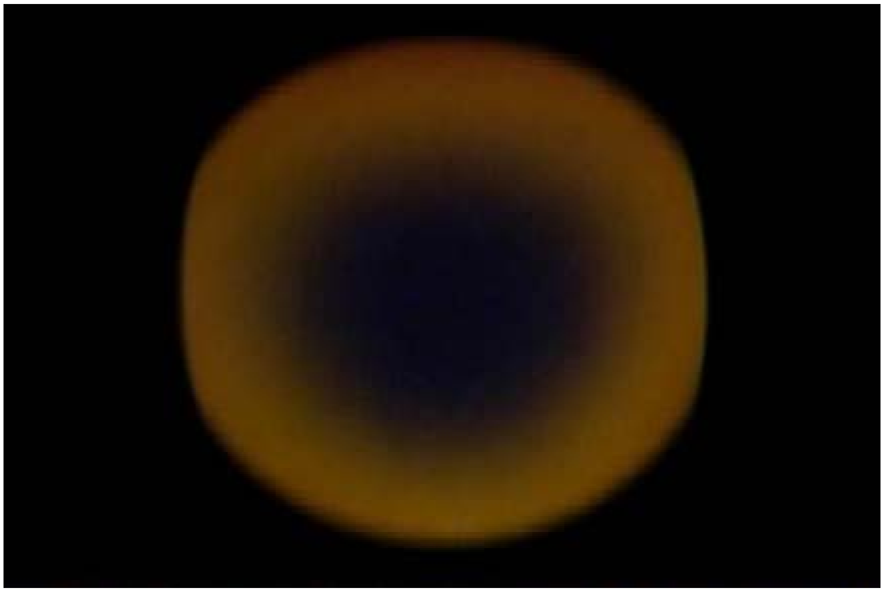
Question #225

One of the most important experiments in establishing the concept of a frame of reference, useful in the study of relativity, was the Michelson-Morley experiment. At the heart of this experiment is the Michelson interferometer, shown in the photograph at the left below, which has now become a staple in the physics laboratory in its own right. A beam of light enters the interferometer through the entrance window **En** at the top of the photograph, strikes a beam splitter **S** and is divided into two equal parts, one continuing downward toward the movable mirror **MM** and one to the left toward the fixed mirror **FM**. Each part reflects off its respective mirror and returns to the beam splitter, where the two beams are recombined and leave the interferometer through the exit window **Ex**. The glass compensator plate **P** makes the length of the light path in glass the same for both beam components. Because one of the beams reflects off the beam splitter externally, with a phase change, and the other beam reflects internally in the the beam splitter without a phase change, when the lengths of the two paths is exactly the same the beams will recombine exactly out of phase with each other. The two beams will therefore interfere destructively when they recombine, creating a dark spot at the center of the pattern, as seen in the figure at the right below. The interferometer pattern is projected onto a screen about three meters from the interferometer by a lens **Lx** positioned at the exit of the interferometer, as can be seen in the figure.


L
M
En
Lx
S
FM
Ex
P
MM
PRECISION INTERFEROMETER

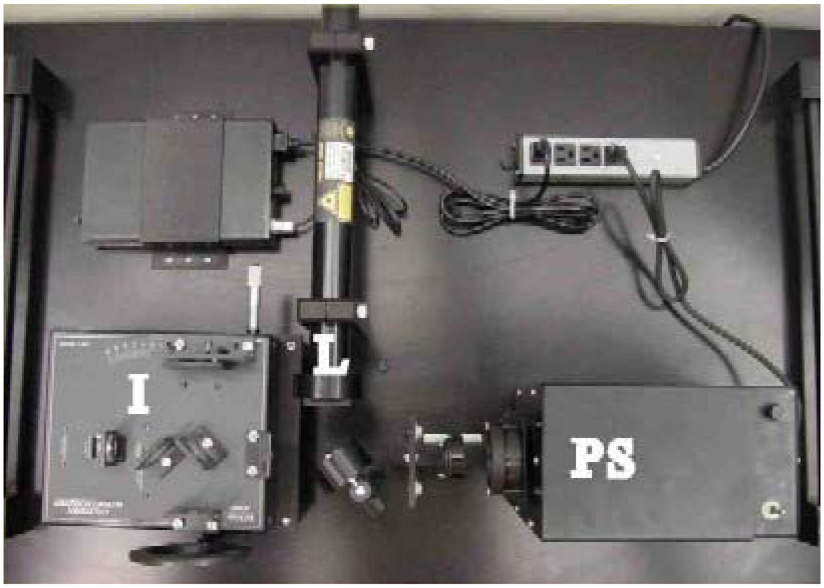

IR
A
C
P



The optical components used to direct the white light into the interferometer are shown in the photograph at the center above: a bright quartz halogen point source **P** at the right is focused into a narrow beam by a condenser lens **C**, passes through an iris aperture **A**, and an infrared filter **IR** to limit heating of optical elements in the interferometer and the concomitant image distortion.

Moving the movable mirror in or out along its optic axis creates a variety of interference patterns that depend in detail on the phase differences between the two reflected components. If the two recombining beams are out of phase, the two beams will intefere destructively along the optic axis, and the center of the pattern will be black, as seen in the photograph at the right above. With monochromatic light the center becomes alternatively black and the color of the light as the position of the movable mirror is changed. With white light, near the equal path length mirror position only one color interferes destructively at a time, creating a series of negative colors: white light minus the spectral color that is interfering destructively. When the path length difference becomes large, the interference becomes very complex for the various component colors, and is very difficult to observe directly; the light pattern remains a constant washed out white color as the mirror position is varied.

The complete setup for producing interference fringes using both a laser **L** and a white light point source **PS** is shown in the photograph below. A mirror, identified as **M** in the photograph at the left above can be inserted to direct the laser beam into the interferometer or removed to allow the white light to enter the interferometer.



Suppose that, beginning at the position where the light paths for the two component beams are exactly equal (shown at the left immediately above) we very slowly and carefully move the movable mirror out, away from the beam splitter where the two beams are separated. What will be the order of the colors produced along the center of the interference pattern? Because there are so many possible hues, we will limit the choice to the three primary colors for lights: red (R), green (G) and blue (B), where white W = R + G + B), and three negative colors: cyan C (C = W - R = G + B), magenta M (M = W - G = R + B) and yellow Y (Y = W - B = R + G). Two additional possibilities are black and white. You can also obtain various hues of each of these major colors, but we will deal with the six major colors defined here plus black and white.

Select which of the following colors you might see as you move the movable mirror **out**, and give the order in which you will see them:

- (a) Red
- (b) Green
- (c) Blue
- (d) Cyan
- (e) Magenta
- (f) Yellow
- (g) Black
- (h) White

Now let us reverse the situation, starting at the equal path length position and moving the movable mirror **in**. Select which of the following colors you might see as you move the movable mirror **in**, and give the order in which you will see them:

- (a) Red
- (b) Green
- (c) Blue
- (d) Cyan
- (e) Magenta
- (f) Yellow
- (g) Black

- (h) White

Click here for Answer #225 after October 3, 2005.

Question of the Week

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For questions and comments regarding the *Question of the Week* contact Dr. Richard E. Berg by e-mail or using phone number or regular mail address given on the Lecture-Demonstration Home Page.