American Journal of Physics

PAPERS | MARCH 01 2026

Interference rings by scattered light

Giuliano Malloci ; Guido Pegna

Am. J. Phys. 94, 202–205 (2026)
https://doi.org/10.1119/5.0278586

Interference rings by scattered light

Giuliano Malloci[a)] and Guido Pegna[b)]
Department of Physics, University of Cagliari, 09042 Monserrato, Cagliari, Italy

(Received 30 April 2025; accepted 25 November 2025)

An experiment on light interference, which can be carried out at a very low cost and more easily than in the past, is revisited. This simple experiment is made possible by the availability of inexpensive collimated laser pointers. The observed circular interference pattern is beautiful; it is a source of wonder; and its interpretation is straightforward. Unlike many interferometers, the one presented in this work does not require alignment, and the interference fringes are well contrasted, stable, and clearly visible even to a large audience in a non-darkened environment. The explanation of the phenomenon has been developed in a straightforward manner, closely aligned with the experimental conditions. In addition, an original implementation is shown that allows the determination of the refractive index or thickness of thin sheets of transparent materials. Finally, a conceptually new interferometric device for determining small displacements and their variations is presented.

https://doi.org/10.1119/5.0278586

I. INTRODUCTION

Transparent or nearly transparent layers, with flat and approximately parallel faces of varying thicknesses, are at the core of many light interference phenomena, including the formation of color bands in soap bubbles and the circular pattern known as Newton's rings.

The interference phenomenon illustrated here takes place between beams of light scattered by microscopic particles that are larger than the wavelength of light (Mie scattering.[1,2]) The fact that scattered light beams can interfere is surprising in itself, since normally interference is seen in more controlled conditions such as transmission and reflection.

This phenomenon has long been known,[3–6] but to our knowledge it is mentioned in only two optics textbook[7,8] and it appears to have found no applications at all. Pohl[4] provides a brief historical introduction, tracing interference by scattered light back to observations made by Isaac Newton while Ref. 5 provides an experimental verification of the phenomenon using natural light. Today, thanks to the availability of inexpensive diode lasers, the phenomenon can be easily reproduced at a very low cost.[9,10] Other researchers have explored its applications in education,[11–15] while peculiar aspects of scattering by evaporating liquid droplets were explained in Ref. 16. In this work, we focus on the beauty of the phenomenon, its unexpected nature, and the sense of wonder it evokes. We also consider practical applications of interference by scattered light that, to the best of our knowledge, have not been considered previously.

We first derive the theory of the phenomenon in a manner that we believe is simpler and straightforward than previous works.[5,12] We additionally illustrate how to easily build and assemble the necessary components and show some of the beautiful images that can be obtained. Finally, in the supplementary material we introduce new possible applications of this effect for the development of two entirely new interferometric measurement systems.

II. THE PHYSICAL PHENOMENON

A thin layer of talcum powder is deposited on the glass surface of a back-silvered mirror and a collimated green laser beam is directed toward the mirror at normal incidence, as seen in Fig. 1. We can perform the analysis in the Fraunhofer regime, with plane waves and parallel rays. The reflected scattered light is seen on a screen positioned 1 m from the mirror and can be recorded using a photographic or a web camera. Scattering by the small particles of talcum powder yields bright and stable circular fringes on the screen. The width of these fringes depends on the geometric parameters of the configuration and the refractive index of the mirror's glass. A photograph of the interference pattern is shown in Fig. 2.

At first glance, it may seem surprising that scattered light can interfere and produce interference fringes like those shown in Fig. 2. This interference demonstrates that when a light wave undergoes elastic scattering, it retains its coherence properties.[17]

Most of the previously reported experiments were performed in the Fresnel limit, and the corresponding analysis is complicated by the geometry of differing angles from the source to the scatterer and from the scatterer to the screen. Deriving the interference equations in the Fresnel limit is lengthy, and in general one cannot get from Fresnel to Fraunhofer regimes except in special cases. The present work avoids the Fresnel to Fraunhofer conversion, thereby simplifying the geometry and reducing the length of the derivation.

III. EXPLANATION OF THE PHENOMENON

The observed pattern shown in Fig. 2 is due to interference between light rays that are forward scattered by a talcum powder particle either before and after they transmit through the glass, reflect off the silvered surface, and transmit back through the glass. The physical situation is schematically depicted in Fig. 3.

The laser beam incident on the mirror is well collimated, and since we are in the Fraunhofer regime, we have plane waves with parallel rays and images at infinity. The talcum powder particles used in this experiment have typical dimensions on the order of tens of μm, much larger than the wavelength of the visible light (chalk and flour have similar

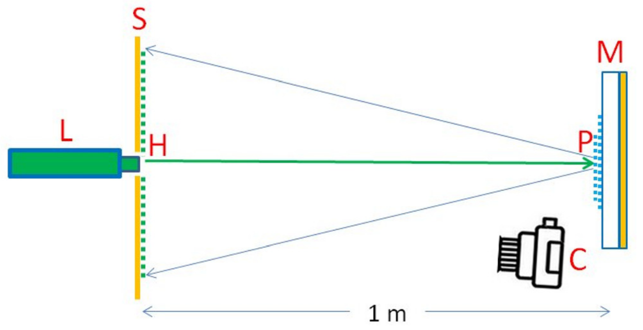

Fig. 1. Schematic setup for visualizing and recording interference fringes produced by scattered light. L: green laser pointer; M: back-silvered mirror with dust particles P on its surface; S: screen where the fringes are projected; H: hole in the screen through which the laser beam passes; and C: photographic or web camera to record the pattern on the screen.

properties and can also be used). Under these conditions, Mie scattering is known to be larger in the forward direction than in the reverse direction by several orders of magnitudes.[2] We may therefore analyze only what happens when light is scattered in the forward direction by the particle P. This condition appears to be well satisfied in the illustrations reported previously,[5,10] but not in others whose geometrical description appears unconvincing.[18] This makes the explanation we provide in the present work substantially simpler and more consistent with the actual experimental setup. When describing the interaction between the light and the particle, we use the following symbols: the wavelength of light is λ, the thickness of the mirror is d, and the refractive index of the glass is n. The laser beam strikes the particle P perpendicularly to the surface of the mirror. The path of ray r_1 is not affected by particle P, and it reflects perpendicularly from the silvered back surface of the mirror. On exiting the glass, it may be scattered by P at an arbitrary angle α.

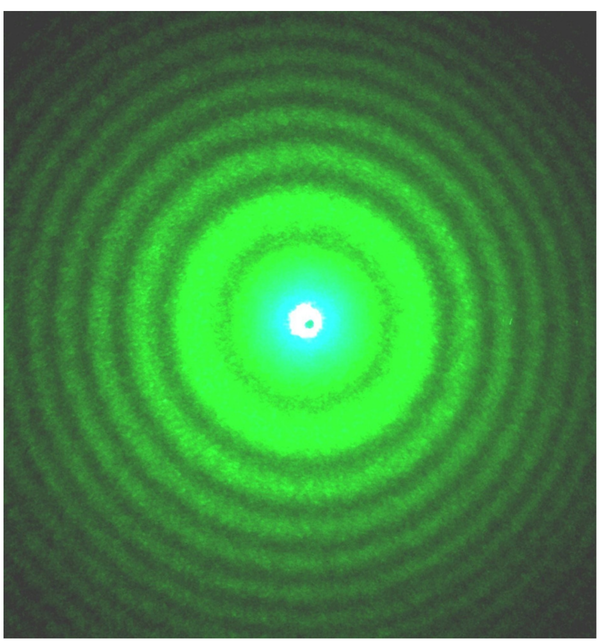

Fig. 2. Interference fringes formed from scattered light by a green laser on a screen placed at a distance of 1 m from a 1 mm thick back-silvered mirror. At the center, the very bright spot of the laser beam passing through the hole in the screen saturates the sensor of the camera. The outermost visible fringes have a diameter of approximately 30 cm.

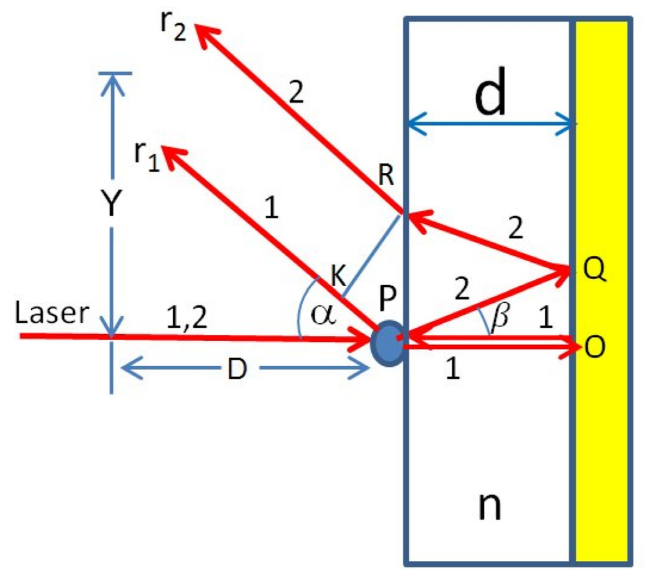

Fig. 3. Schematic representation of light rays scattered by particle P that interfere in the far field, observed on a screen at distance D, where they form a fringe of radius Y.

Another ray, r_2, may be forward scattered by particle P at a small angle β when entering the glass (amplified in Fig. 3 for the sake of clarity), such that after reflection and subsequent refraction, it emerges at the same angle α toward the far screen placed at the distance D, so that r_1 and r_2 will interfere when they reach the screen at radius $Y = D/\sin\alpha$.

The two rays that have traveled different optical paths may interfere constructively (bright fringe) or destructively. The geometrical path l_1 of the ray r_1 is l_1 = PO + OP + PK = 2PO + PK, and for the ray r_2, l_2 = PQ + QR = 2PQ. The optical paths are therefore for l_1: $2nd$ + PK, and for l_2: $2nd/\cos\beta$. We must calculate PK.

Since PR = 2OQ = 2 $d \tan\beta$, and Snell's law requires $\sin a = n \sin\beta$, we have

$$\mathrm{PK} = \mathrm{PR}\,\sin a = \mathrm{PR}\,(n\,\sin\beta), \tag{1}$$

which allows

$$\mathrm{PK} = 2nd\,\tan\beta\,(n\,\sin\beta) = 2nd\,\sin^2\beta/\cos\beta. \tag{2}$$

The optical path difference Δl is therefore given by

$$\Delta l = 2\mathrm{nd}\left(1 + \sin^2\beta/\cos\beta - 1/\cos\beta\right),$$

which simplifies to

$$\Delta l = 2\mathrm{nd}\,(1 - \cos\beta). \tag{3}$$

We will observe a luminous fringe at the screen if the above optical path difference satisfies the condition

$$\Delta l = \mathrm{k}\,\lambda \quad (\mathrm{k} = 0, 1, 2, \ldots),$$

where the integer k is the interference order and λ the wavelength of light.

From Eq. (3), we want to express the optical path difference Δl as a function of measurable quantities such as the screen distance D and the radius Y of luminous interferences fringes. Since $\cos\beta = (1-\sin^2\beta)^{1/2}$ and for small values of the argument we can use the approximation $(1-a^2)^{1/2} = 1 - 1/2a^2$, Eq. (3) can be expressed as follows:

$$2\text{nd}(1-\cos\beta) = 2\text{nd}\left[1-\left(1-\frac{1}{2}\sin^2\beta\right)\right] = k\lambda. \quad (4)$$

By exploiting Snell's law $n \sin \beta = \sin \alpha$, and using the small-angle approximation $\sin\alpha \cong \text{tg}\,\alpha = Y/D$, we finally get the sought condition for luminous fringes,

$$\Delta l = \frac{d}{n}\left(\frac{Y}{D}\right)^2 = k\lambda. \quad (5)$$

The refractive index n of the glass can therefore be determined as

$$n = \frac{d}{k\lambda}\left(\frac{Y}{D}\right)^2. \quad (6)$$

Equation. (6) allows determining the refractive index n of the glass from the radius Y of a bright fringe of order k, given the mirror's thickness d and the wavelength λ of the laser light.

Equation (6) is consistent with Eq. (9) from Ref. 14 as well with Eq. (9) reported in Ref. 5 in the limit $D \gg \lambda$. In both works, the theory of the phenomenon was conducted in the Fresnel regime of diverging rays.

Due to the use of small-angle approximations, this result becomes less exact at larger angles, with an error of 2% at $\tan\alpha = 0{,}15$.

IV. EXPERIMENTAL SETUP

The simplest and fastest way to show interference fringes from scattered light is to place a mirror with a very thin layer of talcum powder on the floor and, in a darkened room, shine a laser beam onto its surface. With the laser beam vertical, the fringes will be projected onto the ceiling. For a more stable setup suitable for measurements, it is necessary to use supports that keep the laser module horizontal and position the mirror approximately 20 cm above the work surface. A possible suggestion for its construction is shown in Fig. 4

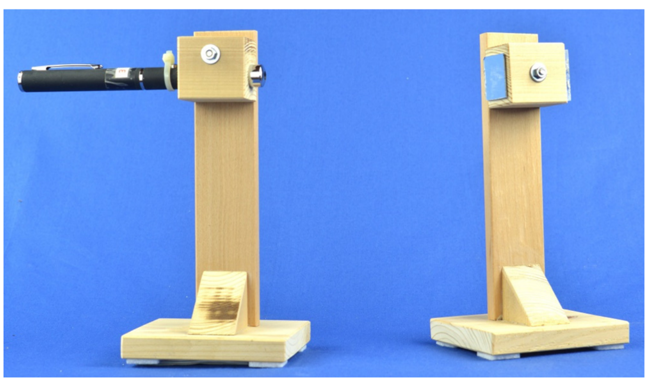

Fig. 4. A practical setup to observe interference from scattered light: the support for the laser module (left) and for the mirrors (right). In this simple setup, the laser and the mirror are attached to wooden blocks that can rotate around a horizontal pivot for adjustments. Up to four mirrors can be placed on the same block. The laser pointer protrudes a bit from the wooden block in order to support the white cardboard screen with a center hole of the same diameter.

where the support for the mirror can also be seen. The mirror is attached to the wooden block with double-sided tape, allowing for easy replacement with other mirrors of different thicknesses.

Green laser pointers like the one shown in the figure can be purchased at a very low cost.[19] They are preferable to those of other wavelengths due to their high visibility. The mirror can be obtained from a glazier in the form of a square with a side width of 3 or 4 cm and will cost almost nothing. The standard thicknesses of commercial mirrors are 3 or 5 mm. A mirror with a thickness of 1 mm, which produces wider fringes, was obtained from an inexpensive make-up compact.

To apply a thin layer of powder to the mirror, a soft brush can be dipped into the powder and then gently passed over the mirror. Any excess will fall off by lightly tapping the support. For vertical alignment, the wooden block holding the laser is rotated around its pivot until the beam is approximately horizontal and reaches the distant mirror. The inclination of the mirror is then adjusted by rotating its block so that the reflected beam falls into the hole in the screen. Horizontal alignment is achieved by rotating both supports on their base. Nothing else is needed. It is astonishing that the fringes appear immediately and that they are clearly visible and stable. They can potentially be enhanced for greater contrast by directing the laser spot onto a part of the mirror where the dust layer is more favorable. Instead of talcum powder, other powders such as chalk, flour, or lycopodium powder can be used. Lycopodium spores are considered by some authors[20] in interference and diffraction experiments due to their high dimensional uniformity (32–34 μm), although no differences with other powders have been observed in forward scattering.[21]

V. AN EXAMPLE OF DETERMINATION

To test formula (6), the experiment was set up as schematized in Fig. 1, using the laser and mirror supports depicted in Fig. 4. The experimental parameters were as follows: thickness of the mirror: $d = 1.01$ mm; talcum powder; laser wavelength $\lambda = 532$ nm; distance between the screen and the mirror: $D = 1$ m. The radius of the third fringe ($k = 3$) is found to be $Y = 4.8$ cm. From Eq. (6), with all the quantities expressed in m,

$$\text{n} = \frac{d}{k\lambda}\left(\frac{Y}{D}\right)^2 = \frac{1.01\times10^{-3}}{3\cdot 5.32\times10^{-7}}\left(\frac{0.048}{1}\right)^2 = 1.50,$$

which differs from the tabulated value for crown glass ($n = 1.513$[22]) by about 1%.

Two more applications of the described phenomenon are presented in the supplementary material associated with this paper. They show respectively the determination of the refractive index or the thickness of a very thin transparent sheet and a conceptually new interferometric apparatus for the determination of small displacements.

VI. CONCLUSIONS

A beautiful phenomenon, rarely discussed in textbooks or the pedagogical literature, has been illustrated and revisited: interference of a laser light beam scattered by microscopic particles. The experiment is extremely easy to set up, costs very little, and requires no more than a few minutes for setup. Unlike almost all light interference experiments, it does not require any alignment of optical components after the initial, very simple, and non-critical setup. The mirrors are standard small squares with reasonably parallel surfaces cut from commercial slabs. The supports for the optical components are easy to build.

We have revisited the theoretical explanation of the phenomenon along lines not yet present in the literature and more directly connected to the geometry and optics of the system. We have shown how to use a similar apparatus to determine the refractive index of a transparent material and how to measure small displacements.

SUPPLEMENTARY MATERIAL

Please click on this link to access the supplementary material, which includes information on determining the refractive index of a sheet and on measuring small displacements. Print readers can see the supplementary material at https://doi.org/10.60893/figshare.ajp.c.8170607.

ACKNOWLEDGMENTS

The authors wish to thank Dr. Marcello Lissia (INFN Cagliari-Italy) and Dr. Emiliano Ippoliti (Forschungszentrum, Jülich-Germany) for useful discussions and advice.

AUTHOR DECLARATIONS

Conflict of Interest

The authors have no conflicts to disclose.

[a]Electronic mail: giuliano.malloci@unica.it, ORCID: 0000-0002-5985-257X.
[b]Electronic mail: guido.pegna@unica.it, ORCID: 0000-0003-4782-945X.

[1]R. M. Drake and J. E. Gordon, "Mie scattering," Am. J. Phys. **53**(10), 955–962 (1985).
[2]C. F. Bohren and D. R. Huffman, *Absorption and Scattering of Light by Small Particles*, 1st ed. (Wiley-Interscience, New York, 1983), p. 541.
[3]J. M. Burch, "Scatter fringes of equal thickness," Nature **171**, 889–890 (1953).
[4]R. W. Pohl, "Discovery of interference by Thomas Young," Am. J. Phys. **28**(6), 530–532 (1960).
[5]A. J. de Witte, "Interference in scattered light," Am. J. Phys. **35**(4), 301–313 (1967).
[6]C. Pontiggia and L. Zefiro, "An experiment on interference in scattered light," Am. J. Phys. **42**(8), 692–694 (1974).
[7]E. Hecht and A. Zajac, *Optics*, 2nd ed. (Addison-Wesley, Reading, MA, 1987), p. 378.
[8]M. Françon, "Information processing using speckle patterns," in *Laser Speckle and Related Phenomena*, 2nd ed., edited by J. C. Dainty (Springer-Verlag, Berlin, 1987), p. 171.
[9]S. K. Derby and H. Kruglak, "Interference fringes with a laser," Am. J. Phys. **64**(4), 508 (1996).
[10]6D30.58, Interference—Dusty Mirror, <https://instructional-esources.physics.uiowa.edu/6d3058-interference-dusty-mirror>
[11]J. Gonzalez, A. Bravo, and K. Juarez, "Interference of laser light scattered by 'dusty' plane mirror," Am. J. Phys. **67**(9), 839–840 (1999).
[12]N. J. Bridge, "A novel effect of scattered-light Interference in misted mirrors," Phys. Educ. **40**(4), 359–364 (2005).
[13]W. Suhr and H. J. Schlichting, "Coloured rings produced on transparent plates," Phys. Educ. **42**(6), 566–571 (2007).
[14]C. A. Sawicki, "Easy and inexpensive demonstration of light interference," Phys. Teach. **39**(1), 16–19 (2001).
[15]O. Voronkin and S. Lushchin, "Demonstration experiment and theoretical model of light interference with small particles," Phys. Educ. **60**(4), 045002 (2025).
[16]G. L. Ngo, Q. T. Pham, N. D. Lai, and D. B. Do, "Interference patterns produced by an evaporating droplet on a horizontal surface," Am. J. Phys. **89**(9), 862–868 (2021).
[17]A. K. Aggarwal and P. C. Gupta, "Scatter light interference using laser speckles," Am. J. Phys. **46**(11), 1193–1193 (1978).
[18]A. Pal, P. Panchadhyayee, K. R. Sahu, and D. Syam, "A novel method for measurement of the refractive indices of transparent solid media using laser interferometry," Phys. Teach. **60**(1), 51–55 (2022).
[19]Green laser pointers like the one in Fig. 4 can be purchased on eBay for less than \$10.
[20]O. Voronkin and S. Lushchin, "Study of light diffraction and interference by lycopodium spores based on their morphological characteristics," Eur. J. Phys. **46**(5), 055802 (2025).
[21]P. Gautam, H. Moosmüller, J. B. Maughan, and C. M. Sorensen, "Light scattering from spherical and irregular particles over a wide angular range," Aerosol Sci. Technol. **58**(9), 1053–1062 (2024).
[22]D. R. Lide, *CRC Handbook of Chemistry and Physics, Internet Version 2005* (CRC Press, Boca Raton, FL, 2005). The value reported is found in pages 10–217 for the wavelength of 0.546 μm.