

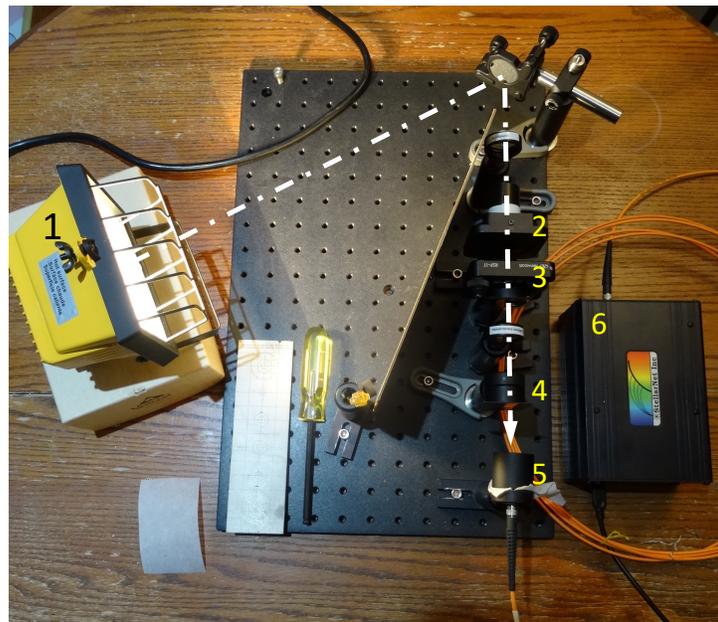
# Birefringence in transparent household films: Quantitative measurement and dazzling demonstrations

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**Abstract:** I describe a simple spectroscopic method for measuring birefringence in household films such as adhesive tape and kitchen film. Using an incandescent light source provides students direct appreciation for the wavelength-dependent nature of the phenomenon. © 2021 The Author(s)

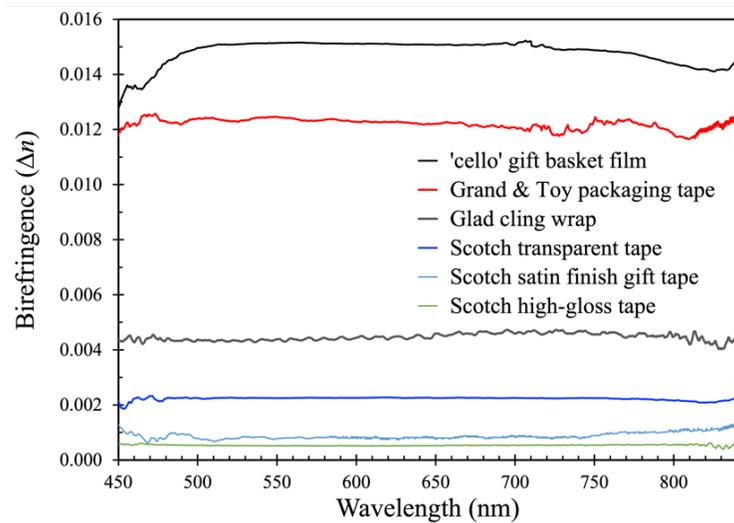
Optical birefringence is a material property that refers to a difference in index of refraction that depends on the polarization and propagation direction of light. Because birefringence is the central phenomenon used for many important technological applications such as LCD screen displays, modern 3D glasses, and microscopy, it is an important optical topic of study. Academically, this topic is usually treated within the framework of polarization because it is the direction of electric field that experiences distinct indexes of refraction in anisotropic (i.e. birefringent) materials. For centuries, Calcite has remained the quintessential example of a birefringent material. As such, the canonical demonstration of birefringence remains the display of double-refraction in calcite; largely because its birefringence is so large, but also because the observation of double-refraction does not require any preparation of the polarization state of the light. However, while birefringence is at the heart of double-refraction, the latter is a challenging concept to describe, and its demonstration is often unimpressive. Beyond calcite, birefringence in ‘plastics’ and polymers has also become a mainstay textbook example of birefringence. In particular, the fact that household films such as kitchen wrap and adhesive tape can act as retarders or ‘waveplates’ remained a common feature in polarization chapters of optics textbooks. become increasingly common in optics textbooks. Despite the enticing visual effects of viewing bright tape between crossed-polarizers, the mathematical and quantitative details of such birefringence are also important and easily accessible via simple modern lab equipment.



**Fig. 1.** Photograph of layout of polarimetric gate for measuring birefringence in polymer films. (1) Incandescent halogen spotlight as light source. (2) Initial gate polarizer. (3) 1” aperture rotation mount affixed with cellophane sample. (4) sheet polarizer acting as analyzer taped onto a 1” rotatable lens mount. (5) multimode fibre receiving mount with a sheet of tissue paper acting as a diffuser stretched between 1” lens tubes. (6) USB spectrometer with multimode fibre input controlled by a tablet computer (not shown).

Over the years there have been numerous investigations of birefringence in transparent polymer films. Most of these investigations measure the index of refraction ( $n$ ) or birefringence ( $\Delta n$ ) at single or discrete wavelengths; usually chosen by the availability of laser sources. It is difficult to discern whether the ubiquity of using lasers for lab demonstrations is pedagogically driven by a desire to keep measurements conceptually restricted to single wavelengths, or simply by a naïve presumption that a coherent light source is needed. Nonetheless, there are broader pedagogical advantages to conducting conceptually-simple but technologically sophisticated lab experiments involving incoherent ‘white’ light.

In this presentation I describe a simple and inexpensive approach to quantitatively measure the birefringence of transparent tape and other transparent films across the visible spectrum (see Fig. 2). With simple equipment that includes cheap sheet polarizers, standard lab optics, a ‘portable USB spectrometer’, and an incandescent light source, this experiment is ideal for junior university/college and ambitious senior high school physics classrooms (see Fig. 1). In addition, I will show simple but eye-popping demonstrations that provide complementary qualitative insight into the connection between retardance addition/subtraction and polarization-filtering colours (see Fig. 3). Such demonstrations are accessible both practically and conceptually to student at various educational levels.



**Fig. 2.** Measured birefringence from transparent films and adhesive tapes made of a variety of polymer backing materials, including high-birefringence Bi-axially oriented polypropylene (gift basket film, packaging tape), polyethylene (kitchen film), and low-birefringence polyolefin (Scotch gift-wrap tapes).



**Fig. 3.** Clear birefringent gift-basket wrap layered and viewed between two polarizers. This six-layer arrangement provides a demonstration of additive and subtractive birefringence, wherein layers oriented in parallel add and layers oriented at 90 subtract. The Closed Gate arrangement (middle panel) is placed between crossed-polarizers. In the Open Gate arrangement, the two polarizers are aligned with parallel polarizations.