

# PURKINJC-SANSON IMAGES

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## PURKINJC-SANSON IMAGES

**Primary Disciplinary Field(s):** Ophthalmology, Physiological Optics, Biophysics

### 1. Core Definition

The term **Purkinje-Sanson images** refers to the series of reflections of an external light source (such as a candle or a small lamp) that are visible upon examining the human or animal eye. These images are generated by the successive reflection of light from the various curved surfaces of the ocular media, primarily the anterior and posterior surfaces of the cornea and the anterior and posterior surfaces of the crystalline lens. Although commonly known as **Purkinje images**, the full designation includes Louis Sanson due to his critical contributions to the understanding and measurement of these reflections, particularly the subtle reflections arising from the internal structure of the eye. The presence, location, size, and orientation of these reflections provide crucial information about the optical characteristics and anatomical alignment of the internal structures of the eye, forming the basis for numerous clinical and research measurements in vision science.

The standard definition of the **Purkinje images** enumerates four distinct reflections, though the original work often focused on the three most easily observable ones. These reflections are essentially specular reflections--mirror-like reflections that occur when light hits a smooth boundary between two media with different refractive indices. Because the cornea (air-to-cornea, cornea-to-aqueous humor) and the lens (aqueous humor-to-lens, lens-to-vitreous humor) form such boundaries, they act as complex curved mirrors. The study of these images is fundamental to understanding ocular physiology, particularly how the eye manages the refraction of light onto the retina, and how changes in geometry (such as accommodation or pathological deformation) affect visual function.

The source material specifically highlights three components observed historically: a reflection from the outer surface of the **cornea**, a reflection from the inner surface of the **cornea**, and a reflection from the outer surface of the **lens**. While the first reflection is dominant and the last is visible, the second reflection from the posterior corneal surface is often faint due to the small difference in refractive index between the cornea and the aqueous humor. The complete set of four images, which includes the reflection from the posterior lens surface, is necessary for a comprehensive analysis of the optical system, especially when modeling the eye under conditions of accommodation.

### 2. Etymology and Historical Development

The **Purkinje-Sanson images** are named in honor of two pioneering scientists who independently

and collaboratively contributed to their discovery and analysis: Jan Evangelista Purkyn? (1787-1869) and Louis Sanson (1790-1841). Jan Purkyn?, a Czech anatomist and physiologist, is generally credited with the initial detailed observation and description of the reflections from the anterior corneal surface (P1) and the anterior and posterior lens surfaces (P3 and P4) in the early 19th century, specifically around 1823. His foundational work in physiological optics laid the groundwork for quantifying the curvature of the ocular media, although precise measurements were challenging given the technology of the time.

Louis Sanson, a French physician and surgeon, significantly advanced the methodology for analyzing these images. In 1837, Sanson used the first three images (P1, P2, and P3) to develop a practical method for clinically determining the radius of curvature of the crystalline lens and the cornea *in vivo*. Sanson's refinement of the observation technique, which involved careful measurement of the relative positions of the images, transformed the observation from a physiological curiosity into a viable diagnostic tool. Therefore, the inclusion of Sanson's name acknowledges the transition of the phenomenon into a measurable and clinically relevant concept, particularly for studying conditions like cataracts or changes in accommodation.

The subsequent history of the **Purkinje images** involved their integration into schematic eye models, such as those developed by Hermann von Helmholtz and later refined by Allvar Gullstrand. These models used the measured radii of curvature derived from the images to predict the overall refractive power of the eye. Modern technology, including videography and specialized tracking equipment, has made the continuous, dynamic measurement of all four images possible, allowing researchers to accurately track small eye movements (microsaccades) and assess changes in the lens shape during the process of accommodation with unprecedented precision.

### 3. Key Characteristics and Components (P1 through P4)

The complete set of **Purkinje images** consists of four distinct reflections, each possessing unique characteristics regarding brightness, orientation, and movement, determined by the surface from which the light reflects. Understanding these individual components is essential for using the images for biometric measurements.

**Purkinje Image I (P1):** This is the reflection from the **anterior surface of the cornea**. P1 is the brightest and clearest of all the reflections because the interface between air and the cornea represents the largest change in refractive index in the anterior eye. P1 is upright (erect), virtual, and typically appears as a small, sharp point of light centered on the pupil. Due to its brightness and stability, P1 is often used as a primary reference point in eye tracking systems, known as the corneal reflection (CR).

**Purkinje Image II (P2):** This reflection originates from the **posterior surface of the cornea**. P2 is extremely faint and difficult to observe without specialized equipment because the refractive index

difference between the cornea and the aqueous humor is relatively small. Like P1, it is upright and virtual. Although challenging to detect, P2 is sometimes used in advanced optical modeling to precisely determine corneal thickness (pachymetry).

**Purkinje Image III (P3):** This reflection comes from the **anterior surface of the crystalline lens**. P3 is fainter than P1 but usually brighter than P2. It is upright and virtual. Crucially, the position and size of P3 change significantly during **accommodation** (the eye's focusing mechanism). As the lens changes shape to focus on near objects, the radius of curvature of the anterior lens surface decreases, causing P3 to become smaller and move anteriorly.

**Purkinje Image IV (P4):** This reflection originates from the **posterior surface of the crystalline lens**. P4 is unique among the four primary images because it is **inverted** (real image). This inversion occurs because the posterior lens surface acts as a concave mirror due to the relationship between the light rays and the refractive indices of the media. P4 is smaller than P3 and also changes dramatically during accommodation, often moving closer to the lens capsule as the posterior surface flattens slightly. P4 is the most critical image for dynamically tracking lens deformation during accommodative effort.

#### 4. Optical Principles and Physics

The generation of **Purkinje-Sanson images** relies entirely on the fundamental principles of reflection and refraction at curved surfaces, governed by Snell's law and the mirror equation. Each surface of the cornea and lens functions as a spherical or near-spherical mirror. The brightness of a particular image is proportional to the difference in refractive indices ( $n_1 - n_2$ ) between the two media forming the interface. Since the air-to-cornea interface ( $\Delta n \approx 0.4$  to  $0.5$ ) is the largest difference, P1 is the strongest reflection. Conversely, the cornea-to-aqueous interface has a negligible index change, making P2 very faint.

Furthermore, the orientation and nature (real or virtual) of the image are determined by the curvature of the reflecting surface. Both the anterior cornea and the anterior lens surfaces are convex toward the incident light, causing them to behave like convex mirrors, which always form upright, virtual images (P1, P2, P3). In contrast, the posterior surface of the crystalline lens is typically concave toward the incident light passing through the eye's interior. When light reflects off this surface and travels back through the lens and cornea, the optical geometry results in the formation of a real, inverted image (P4). This unique inversion confirms the anatomical and optical properties of the posterior lens capsule.

The application of these principles allows researchers to calculate the radius of curvature ( $R$ ) for each surface using the measured size ( $h$ ) and location ( $d$ ) of the reflection relative to the light source. By treating the eye as a series of co-axial refractive spheres (the basis of the Gullstrand schematic eye model), the entire refractive power of the visual system can be modeled. Any

clinical or age-related change affecting the radii of curvature--such as corneal flattening or lenticular swelling--will manifest as predictable changes in the size and relative position of the **Purkinje images**.

## 5. Clinical and Research Applications

The precise measurement of **Purkinje-Sanson images** is indispensable across several clinical and research domains within ophthalmology and visual neuroscience. Their primary application lies in biometry and the assessment of dynamic visual processes, making them a cornerstone of modern optical diagnostics.

One of the earliest and most widespread applications is **keratometry** (measurement of corneal curvature). P1, being the brightest and most stable, is the image measured by traditional keratometers to assess the radius of curvature of the anterior cornea. Accurate keratometry is crucial for fitting contact lenses, diagnosing astigmatism, and pre-surgical planning for refractive procedures like LASIK. Similarly, measuring the relative positions of P3 and P4 is essential for **phakometry**--the measurement of the thickness and curvature of the crystalline lens, which is vital for calculating the power of intraocular lenses (IOLs) used in cataract surgery.

In research settings, the most advanced use of the **Purkinje images** is in **eye tracking** (oculography). By simultaneously tracking the movement of P1 (fixed relative to the corneal apex) and the center of the pupil, researchers can calculate the precise angle of rotation of the eyeball in three dimensions. This dual-Purkinje image tracking method offers superior accuracy compared to methods relying only on the corneal reflection, enabling highly precise studies of saccades, fixational eye movements, and visual stability. Furthermore, the dynamic analysis of P3 and P4 during focusing allows for quantitative studies of the mechanism and extent of **accommodation**, which naturally declines with age (presbyopia).

## 6. Measurement Techniques and Technology

The accurate capture and analysis of **Purkinje images** require specialized optical devices that minimize error introduced by subject movement and ambient light. The techniques have evolved dramatically from simple manual observations to highly automated, computerized systems.

**Keratometry and Phakometry:** Traditional techniques involve a Keratometer, which projects a calibrated target (mires) onto the cornea. The observer aligns the reflected images of these mires (P1) and adjusts the instrument until the reflected images are in focus or alignment, allowing a direct readout of the corneal radius of curvature. Phakometry historically involved instruments like the Phakometer, which used telescopic optics to measure the relative separation of P3 and P4 to calculate lens curvature and thickness, often requiring dilation of the pupil for adequate visualization.

**Dual-Purkinje Image Eye Tracking:** This advanced method, widely used in visual neuroscience, employs infrared light sources and sophisticated video cameras (Charge-Coupled Devices or CCDs) to capture P1 and P4 simultaneously at high frame rates (e.g., 500 Hz or higher). The system continuously calculates the positional difference between the center of the pupil and the center of P1, correcting for head movement, and then uses P4 to provide a more stable reference point for true retinal angle. This technique is often sensitive enough to detect eye movements down to a few minutes of arc.

**Scheimpflug Imaging and Optical Coherence Tomography (OCT):** While not strictly a measurement of the images themselves, these modern imaging modalities provide high-resolution cross-sectional data of the anterior segment of the eye, offering highly accurate, non-contact measurements of corneal and lens geometry, which complements and validates the data derived from **Purkinje image** analysis. OCT, for instance, can measure the posterior corneal curvature (related to P2) with far greater precision than visual observation.

## 7. Debates, Criticisms, and Limitations

While the concept of **Purkinje-Sanson images** is fundamental, its utility in modeling the eye is subject to several theoretical and practical limitations. The primary debate centers on the assumption that the ocular surfaces are perfectly spherical, which is necessary for simple calculation using the mirror equation.

In reality, both the cornea and the lens exhibit significant **asphericity** (deviation from a perfect sphere). The cornea typically flattens toward the periphery (prolate shape), and the anterior lens surface also changes its aspheric profile during accommodation. When calculations assume a spherical surface, errors can accumulate, particularly in peripheral measurements or when analyzing eyes with high levels of aberration. Modern studies often incorporate complex polynomial models (e.g., Zernike polynomials) to describe these non-spherical shapes, moving beyond the simple assumptions inherent in the initial **Purkinje-Sanson** methodology.

A further limitation lies in the difficulty of consistently observing P2 and P4. P2 is almost invisible due to low reflectance, and P4 is located deep within the eye, often obscured by lens opacity (cataracts) or requiring significant pupil dilation, which itself can affect the accommodative state. Furthermore, the refractive index of the crystalline lens is not uniform but exhibits a **gradient index (GRIN)** profile, meaning the index of refraction increases towards the center of the lens nucleus. Simple models assume a homogeneous index, leading to minor inaccuracies in calculating the effective refractive power of the lens based on surface reflections alone. Despite these limitations, the stability and relative ease of measuring P1 ensures that the concept of **Purkinje images** remains a vital reference point in ophthalmological science.

## Further Reading

[Purkinje Images \(Wikipedia\)](#)

[Ophthalmology \(Wikipedia\)](#)

[Physiological Optics \(Wikipedia\)](#)

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