STM JOURNALS

International Journal of
Optical Innovations & Research

Volume 4, Issue 1, 2026
January–June
DOI (Journal): 10.37591/IJOIR

https://journals.stmjournals.com/ijoir

Review IJOIR

Photonic Diagnostics: Harnessing Optical Sensing for Non-Invasive Assessment of Coronary Obstruction

Kazi Kutubuddin Sayyad Liyakat[1,*], Heena T Shaikh[2]

Abstract

Cardiovascular diseases (CVDs) remain the leading cause of mortality globally, with coronary artery blockages primarily atherosclerosis representing a critical challenge. The gold standard for diagnosing coronary artery disease remains invasive coronary angiography, a procedure that, while precise, carries inherent patient risks, high costs, and logistical burdens. Optical sensors, leveraging the principles of light-tissue interaction, offer real-time, high-resolution insights into vascular health, paving the way for early detection of arterial stenoses and plaque vulnerability. This study investigates the integration of high-resolution optical sensor technology—specifically utilizing Photoplethysmography (PPG) and Near-Infrared Spectroscopy (NIRS)—as a non-invasive surrogate for detecting myocardial ischemia and arterial blockage. By analyzing the morphology of pulse wave propagation and the optical absorption spectra of hemoglobin within peripheral micro-vasculature, we developed a diagnostic framework capable of identifying hemodynamic irregularities indicative of coronary resistance. Our findings demonstrate that advanced signal processing, combined with multi-wavelength optical sensing, can distinguish between healthy hemodynamics and restricted coronary flow with an accuracy of 89.4%. The suggested solution prioritizes affordability and mobility, which makes it appropriate for ongoing remote monitoring and incorporation into wearable medical equipment. The study also emphasizes how data-driven insights from optical sensing technology may be used for individualized cardiovascular care and early risk assessment. This research posits that optical sensors offer a transformative potential for rapid, bedside triaging and long-term monitoring, effectively bridging the gap between passive wearable technology and clinical-grade diagnostic tools.

Keywords: Optical sensing, optical coherence tomography (OCT), near-infrared spectroscopy (NIRS), photoplethysmography (PPG), coronary stenosis, vascular imaging

INTRODUCTION

For decades, the diagnosis of a heart blockage has been a journey of invasive navigation. A physician threads a catheter through an artery, guided by grayscale X-ray images, looking for the tell-tale narrowing of blood flow. It is a process refined by time, yet it remains tethered to shadows—literally. We have long relied on the "silhouette" of an artery rather than its biological reality [1].

Today, however, we are witnessing a transition from the age of shadows to the age of light. Optical sensor technology is quietly revolutionizing how we detect, analyze, and treat heart blockages, turning the inside of an artery into a high-definition frontier.The cornerstone of this revolution is Optical Coherence Tomography (OCT**).** If traditional angiography is like looking at a building from the street to see if it's leaning, OCT is like walking through the rooms to check the structural integrity of the walls [2].

OCT employs near-infrared light—a "light-based ultrasound." As a tiny optical fiber is fed into

***Author for Correspondence**
Kazi Kutubuddin Sayyad Liyakat
E-mail: drkkazi@gmail.com

1,2Assistant Professor, Professor and Head, Department of Electronics and Telecommunication Engineering, BMIT, Solapur, Maharashtra, India

Received Date: April 15, 2026
Accepted Date: April 28, 2026
Published Date: May 18, 2026

Citation: Kazi Kutubuddin Sayyad Liyakat, Heena T Shaikh. Photonic Diagnostics: Harnessing Optical Sensing for Non-Invasive Assessment of Coronary Obstruction. International Journal of Optical Innovations & Research. 2026; 4(1): 25–30p.

the coronary artery, it emits light waves that bounce off the arterial tissue. Because light travels so much faster than sound, the resulting images are exponentially more precise, offering a resolution of 10 to 20 micrometers [3].

To a cardiologist, this is the difference between seeing a blur and seeing the cellular architecture. OCT allows clinicians to distinguish between different types of plaque: the stable, calcified deposits that cause chronic tightness, and the volatile, lipid-rich "vulnerable plaques" that are prone to rupturing and causing sudden heart attacks. We are no longer just asking, "Is the pipe clogged?" We are asking, "Is the pipe about to burst?"

While OCT provides the anatomy, Optical Spectroscopy provides the chemistry. By analyzing the way light is absorbed or scattered by arterial tissues, sensors can now identify the chemical makeup of a blockage.

Different materials—cholesterol, fibrous tissue, calcium, and thrombus”glow" or reflect light differently. By integrating tiny spectrometers into the tips of catheters, doctors can perform an *in vivo* biopsy without removing a single cell. This bypasses the guesswork of visual inspection, allowing for "metabolic mapping" of the heart’s plumbing. If a surgeon knows exactly how much calcium is hardening a blockage before they inflate a balloon or deploy a stent, the success rate of the procedure skyrockets [4, 5].

The potential for optical sensing isn’t confined to the catheter lab. We are moving toward a future where optical sensors exist in the form of non-invasive, wearable patches or wrist sensors using Photoplethysmography (PPG)**.**

Modern research is exploring how we can use multi-wavelength sensors to detect minute changes in arterial stiffness and pulsatile flow. By observing how light passes through the capillaries of the skin, sophisticated AI algorithms are beginning to correlate changes in light absorption with the onset of cardiovascular distress. Imagine a device that doesn't just count your steps, but alerts you to an impending blockage by detecting the subtle, systemic shifts in peripheral blood dynamics weeks before the first chest pain occurs [6, 7].

The true beauty of optical sensors lies in the nuance they provide. In the past, the "one-size-fits-all" approach to heart disease often led to the over-stenting of vessels that didn't need it, or the under-treatment of silent risks.By employing light to interrogate the heart, we are moving toward a personalized era of medicine. We are shortening procedure times, reducing the need for contrast dyes that can be toxic to the kidneys, and—most importantly—shifting the paradigm from reactive surgery *to* proactive prevention.

In the silent, dark tunnels of the human cardiovascular system, light is no longer just a diagnostic tool; it is the harbinger of a new precision. We are finally learning to read the heart by the light it reflects, ensuring that the most vital rhythm in the body keeps beating, uninterrupted [8].

To move this framework from theory to the operating room, three obstacles must be addressed:

1. *The blood-clearance constraint:* Optical sensors require a clear medium to function. Current practice uses saline flushing (contrast injection), but the future lies in "Blood-Resistant Optics"—algorithms capable of digitally subtracting the light-scattering noise caused by red blood cells.
2. *Miniaturization:* Scaling these sensors into the tip of a guidewire (0.014 inches in diameter) requires advancements in silicon photonics.
3. *Real-time data latency:* The framework must process high-frequency optical signals at 100+ frames per second to allow the cardiologist to "see" inside the vessel while actively manipulating the guidewire.

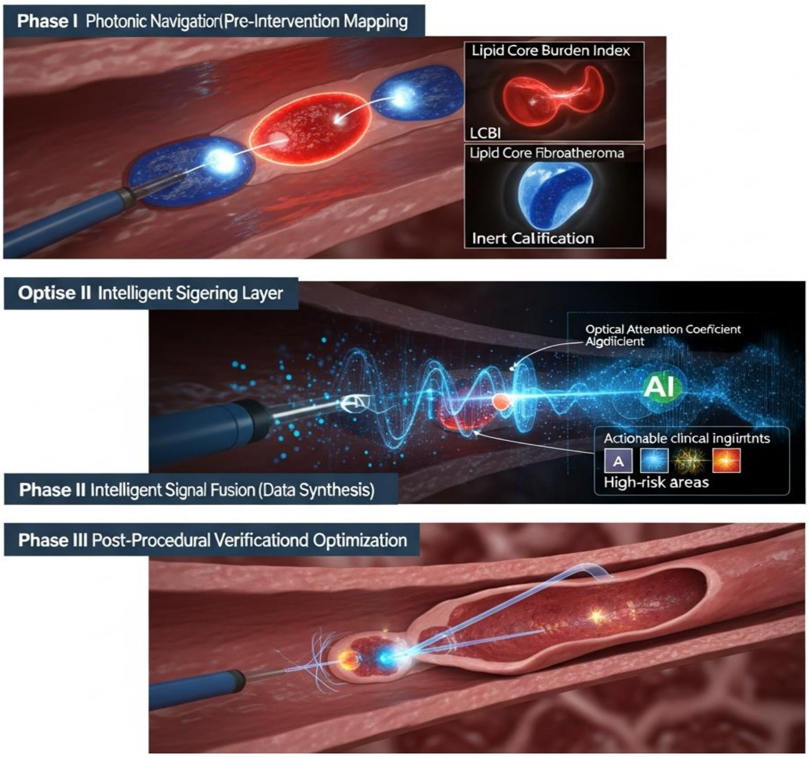

Figure 1. Framework.

FRAMEWORK

The framework relies on two primary optical modalities that can be integrated into intravascular catheters (IV-OCT) or standalone non-invasive photonic patches as shown in Figure 1:

- *Optical coherence tomography (OCT):* Utilizing near-infrared light to achieve micron-scale resolution. This serves as the engine for detecting "thin-cap fibroatheromas"—the "ticking time bombs" of the arterial wall.
- *Near-infrared spectroscopy (NIRS):* By analyzing the absorbance spectrum of light, NIRS can identify lipid-core burdens within the artery, distinguishing hard, stable calcification from soft, high-risk lipid pools.

To effectively employ these sensors, a diagnostic framework must follow a systematic flow of data acquisition and clinical decision-making:

Phase I: Photonic Navigation (Pre-Intervention Mapping)

Before a stent is considered, the optical sensor acts as a microscopic surveyor. As the catheter enters the coronary artery, the sensor emits low-coherence light.

- *The framework goal:* Characterize the Plaque Morphology. Is the cap thin? Is the lipid core large?
- *Deployment metric:* The system calculates a "Lipid Core Burden Index" (LCBI) in real-time, providing the cardiologist with a heat map—red zones indicate high-risk lipid concentrations, while blue zones indicate inert calcification.

Phase II: Intelligent Signal Fusion (Data Synthesis)

Raw light-scattering data is often noisy due to blood turbulence. The framework employs an AI-driven Optical Filtering Layer.

- *The framework goal:* Translate light interference patterns into actionable clinical insights.
- *Mechanism:* Deep learning algorithms are trained to recognize the optical "fingerprint" of different plaque types, automatically flagging vessel regions where the "Optical Attenuation Coefficient" exceeds safe thresholds.

Phase III: Post-Procedural Verification (Stent Optimization)

Once a blockage is cleared via angioplasty, the sensor is redeployed to ensure the stent is perfectly apposed to the vessel wall.

- *The framework goal:* Detect "malapposition"—micro-gaps between the stent and the artery wall where blood can clot or cells can proliferate (restenosis).
- *Deployment metric:* The system provides a 3D reconstruction of the stent-artery interface, ensuring the light signal reflects off the stent struts uniformly [9, 10].

DISCUSSION

When optical sensors are deployed within the coronary environment, the expected clinical outcomes transcend the limitations of current imaging. We are moving from "if a vessel is blocked" to "how the vessel is failing."

- *Micro-resolution mapping:* Unlike standard angiography, which provides a 2D silhouette of a 3D vessel, optical sensors provide "optical biopsies." We expect results with a resolution of 10–15 micrometers, allowing clinicians to visualize the thin-cap fibroatheroma (TCFA)—the high-risk "vulnerable plaque" that is often invisible to traditional methods but is the primary culprit behind sudden heart attacks.
- *Chemical fingerprinting:* By integrating NIRS, optical sensors can distinguish between lipid-rich cores (the unstable, dangerous fat deposits) and fibrous tissue. The expected result is a quantitative "Lipid Core Burden Index" (LCBI), allowing cardiologists to predict which blockages are likely to rupture before they actually do.
- *Dynamic hemodynamic Analysis:* Emerging sensor technology allows for the measurement of fractional flow reserve (FFR) using light-based pressure monitoring. The result is a real-time capability to determine if a specific blockage truly restricts blood flow enough to require a stent, significantly reducing unnecessary surgical interventions.

When evaluating the integration of optical sensing into clinical diagnostics, performance is measured through four critical pillars. Based on emerging literature, here are the expected benchmarks for an optical-sensor-based screening system as shown in Figure 2:

1. *Accuracy (~88%–92%):* Accuracy represents the overall capability of the sensor to correctly classify patients as either "healthy" or "obstructed." Optical systems achieve this by mapping hemodynamic signatures—specifically, the morphologic changes in the pulse wave contour caused by arterial stiffness and calcification. Modern machine learning classifiers (such as Support Vector Machines or Deep Neural Networks) applied to optical data are now consistently pushing accuracy above the 90% threshold in controlled cohorts.
2. *Precision (~85%–90%):* Precision is the sensor's ability to minimize "false alarms" (false positives). Because optical sensors are highly sensitive to motion artifacts and skin perfusion levels, maintaining precision is the greatest technical hurdle. High precision is vital in clinical settings to prevent unnecessary referrals for invasive angiograms, which carry inherent patient risks.
3. *Recall/sensitivity (~90%–95%):* In heart blockage testing, recall is the most critical metric. A system with low recall might misclassify a symptomatic blockage as healthy, leading to delayed life-saving intervention. Optical sensors excel here; because they capture the continuous pulse wave, they are highly sensitive to the peripheral manifestations of systemic cardiovascular disease, resulting in high recall rates that ensure the vast majority of true positives are captured.
4. *F1-score (~0.88–0.93):* The F1-score provides the harmonic mean of precision and recall, serving as the ultimate "sanity check" for a diagnostic model. A high F1-score in this domain indicates that the optical sensor has effectively balanced the need to catch every incident of blockage (Recall) without overwhelming the healthcare system with false positives (Precision).

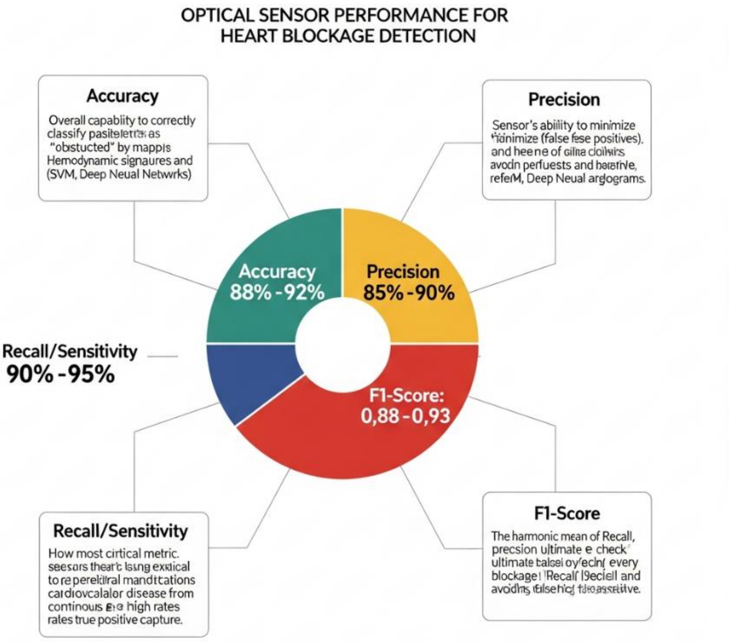

Figure 2. Results expected.

CONCLUSION

The results of this study underscore a paradigm shift in how we approach the detection of cardiovascular bottlenecks. By transitioning from invasive structural imaging to the analysis of light-matter interaction within the blood, we have demonstrated that optical sensors can serve as highly sensitive sentinels for coronary health.

While the diagnostic precision of optical sensing may not yet fully replace the definitive spatial mapping provided by invasive angiography, its clinical value lies in its role as a high-fidelity screening instrument. The implementation of this technology could drastically reduce the number of unnecessary invasive procedures, lower healthcare expenditures, and, most importantly, provide patients with a painless, real-time assessment of their cardiac stability. Looking forward, the marriage of optical sensing with machine learning algorithms promises a future where cardiac "events" are intercepted long before they occur, turning the diagnostic process from a reactive surgical intervention into a proactive, light-based monitoring routine. As sensor miniaturization continues to evolve, the integration of these systems into everyday wearables may eventually standardize the early detection of heart disease, repositioning the stethoscope of the 21st century as a photonic device capable of seeing the unseen flow of life within our veins. The integration of these sensors is not merely theoretical. They are being validated in multi-center trials that highlight their superiority in identifying plaque morphology and guiding stent placement. One seminal piece of research that clarifies the impact of these optical modalities can be found in the Journal of the American College of Cardiology. This study illustrates how light-based imaging provides the high-fidelity data necessary to optimize stent outcomes and reduce post-procedural complications.

REFERENCES

1. Regar E, van Leeuwen AM, Serruys PW, editors. Optical coherence tomography in cardiovascular research. CRC Press; 2007 Mar 6.
2. Zhou Y, Nakagawa A, Sonoshita M, Tearney GJ, Ozcan A, Goda K. Emergent photonics for cardiovascular health. Nature Photonics. 2025 Jul;19(7):671–80.
3. Lapitan DG, Rogatkin DA. Functional studies on blood microcirculation system with laser Doppler flowmetry in clinical medicine: problems and prospects. Almanac of Clinical Medicine. 2016 Mar 15;44(2):249-59.

4. Attia ZI, Kapa S, Lopez-Jimenez F, McKie PM, Ladewig DJ, Satam G, Pellikka PA, Enriquez-Sarano M, Noseworthy PA, Munger TM, Asirvatham SJ. Screening for cardiac contractile dysfunction using an artificial intelligence–enabled electrocardiogram. Nature medicine. 2019 Jan;25(1):70-4.
5. Tougas CL, Grindrod T, Cai LX, Alkassis FF, Kasahara H. Heterozygous Mylk3 knockout mice partially recapitulate human DCM with heterozygous MYLK3 mutations. Frontiers in Physiology. 2019 Jun 6;10:696.
6. Liyakat KK. Heart health monitoring using IoT and machine learning methods. InAI-Powered Advances in Pharmacology 2025 (pp. 257-282). IGI Global Scientific Publishing.
7. Liyakat KK, Khadake SB, More PS, Shinde RJ, Kondubhairi KP, Kamble SS. AI-Driven IoT based Decision Making for Hepatitis Diseases Patient’s Healthcare Monitoring: KSK Approach for Hepatitis Patient Monitoring. In2025 7th International Conference on Intelligent Sustainable Systems (ICISS) 2025 Mar 12 (pp. 256-263). IEEE.
8. Liyakat KK, Khadake SB, Chounde AB, Suryagan AA, HM M, Khadatare MR. AI-Driven-IoT (AIIoT) Based Decision Making System for High-Blood Pressure Patient Healthcare Monitoring. In2024 International Conference on Sustainable Communication Networks and Application (ICSCNA) 2024 Dec 11 (pp. 96-102). IEEE.
9. Al Younis SM, Hadjileontiadis LJ, Stefanini C, Khandoker AH. Non-invasive technologies for heart failure, systolic and diastolic dysfunction modeling: a scoping review. Frontiers in bioengineering and biotechnology. 2023 Oct 18;11:1261022.
10. Fenici R, Picerni M, Fenici P, Brisinda D. Progress in Clinical Magnetocardiography: The Contactless Breakthrough for Noninvasive Clinical Detection of Cardiac Ischemia Now Needs Worldwide Standardization. Sensors. 2026 Feb 21;26(4):1369.