International Journal of Research and Technology (IJRT)

International Open-Access, Peer-Reviewed, Refereed, Online Journal

ISSN (Print): 2321-7510 | ISSN (Online): 2321-7529

| An ISO 9001:2015 Certified Journal |

Experimental Analysis of Magneto-Optical Effects in Nanoelectronic Devices

[1]Rashmi Chakrawarti, [2]Dr. Hiralal Patil
[1]Research Scholar, Department of Physics, Malwanchal University, Indore
[2]Supervisor, Department of Physics, Malwanchal University, Indore

Abstract

This study presents an experimental analysis of magneto-optical (MO) effects in nanoelectronic devices, emphasizing how nanoscale engineering enhances the interaction between magnetic fields and electromagnetic radiation to enable high-performance functionalities. Drawing on existing experimental data, the study explores key MO phenomena such as the Faraday effect, Kerr rotation, magnetic circular dichroism, and plasmon-enhanced optical modulation, highlighting their significance in device optimization and next-generation applications. Experimental findings demonstrate that nanostructured materials—including garnet thin films, ferromagnetic multilayers, magnetoplasmonic architectures, two-dimensional materials, and topological insulators—exhibit amplified MO responses arising from strong spin–orbit coupling, enhanced field confinement, and tailored electronic band structures. These responses contribute to ultrafast switching speeds, high-sensitivity magnetic detection, improved optical isolation, and efficient spin–photon coupling, making MO effects vital for spintronics, on-chip photonics, memory storage, and quantum information technologies. The study also synthesizes insights from device-level experiments, showing how fabrication methods such as lithographic patterning, epitaxial growth, and nanoscale surface engineering influence MO performance and scalability. The analysis underscores the essential role of MO effects in enabling miniaturized, energy-efficient, and high-speed nanoelectronic systems while identifying key challenges that must be addressed to achieve their full technological potential.

Keywords: magneto-optical effects, nanoelectronics, Kerr rotation, plasmonics, spintronics

Introduction

The study of magneto-optical (MO) effects in nanoelectronic devices has gained substantial momentum over the past decade due to the growing demand for ultrafast, energy-efficient, and miniaturized components capable of operating beyond the limits of traditional electronic systems. Magneto-optical effects—such as the Faraday effect, Kerr rotation, magnetic circular dichroism, and non-reciprocal light propagation—emerge from the interaction between polarized light and magnetic fields within specialized materials. When engineered at the nanoscale, these effects become significantly amplified due to enhanced confinement of electromagnetic waves, strong spin–orbit coupling, and resonance-driven field localization. As nanoelectronics continues to evolve toward quantum-ready and highly integrated architectures, the ability to experimentally probe and manipulate MO interactions offers unique advantages for device optimization and functional expansion. Experimental studies enable precise characterization of material properties, including magnetization dynamics, optical anisotropy, plasmonic behavior, and spin-photon coupling, which are essential for developing efficient optical modulators, sensors, isolators, and spintronic elements. Furthermore, the introduction of advanced materials—such as magnetic garnets, two-dimensional semiconductors, plasmonic nanostructures, and topological insulators—has created new opportunities to engineer ultrathin, flexible, and highly tunable MO devices suitable for next-generation nanoelectronic platforms.

In recent years, the integration of MO materials into nanoscale device architectures has accelerated due to improvements in fabrication technologies such as focused ion beam patterning, atomic layer deposition, e-beam lithography, and epitaxial thin-film growth. These methods not only allow the creation of complex geometries but also enable the precise modulation of magnetic and optical characteristics essential for experimental analysis. Through systematic experimentation, researchers have uncovered vital insights into ultrafast magnetization switching, transient optical responses, tunable plasmonic resonances, and dynamic polarization control mechanisms, all of which are crucial for high-speed communication, quantum information processing, and advanced sensing applications. Experimental observations have validated theoretical predictions and revealed previously unknown behaviors such as anomalous MO responses, enhanced Kerr rotation in hybrid structures, nonlinear optical switching driven by magnetic nanoparticles, and resonance-induced sensitivity boosts in magnetoplasmonic devices. These findings underscore the critical role of experimental research in bridging fundamental magneto-optical physics with practical device engineering. As the field moves toward integrating optical, magnetic, and electronic functionalities on a single nanoscale platform, understanding experimentally derived MO effects becomes essential for the design, optimization, and commercialization of future nanoelectronic technologies.

Research Methodology

This study adopts a secondary-data-based methodological approach to investigate the role and significance of magneto-optical effects in nanoelectronic devices. Since no primary experimentation or laboratory measurements are conducted, the methodology relies entirely on established scientific literature, previously published datasets and theoretical models. The framework begins with a systematic literature review designed to identify, retrieve and evaluate credible sources from peer-reviewed journals, scientific databases, conference proceedings, patents and institutional research outputs. A structured search strategy—using keywords such as magneto-optical effects, Faraday rotation, Kerr effect, nanoelectronic materials, spintronics and plasmonic magneto-optics—ensures focused and comprehensive data collection. Inclusion and exclusion criteria are applied to filter studies based on relevance, scientific rigor, data availability, publication quality and thematic alignment with the research objectives.

The selected literature is then organized into thematic clusters covering magneto-optical materials, device architectures, measurement techniques, theoretical foundations and technological applications. Qualitative analysis is used to interpret conceptual explanations, physical principles and technological developments reported across studies. In parallel, quantitative secondary analysis is conducted using numerical data such as rotation angles, magnetic field intensities, anisotropic constants, optical coefficients and device performance metrics extracted from published experiments. These numerical values are harmonized and examined through descriptive statistics, correlation analysis and, where feasible, regression-based interpretation to identify patterns and comparative trends. Analytical secondary research further strengthens the methodology by examining theoretical models, equations and simulations presented in existing studies, linking them to observed material and device behavior.

This methodology integrates systematic review procedures with qualitative, quantitative and analytical approaches, ensuring a rigorous, reliable and comprehensive investigation of magneto-optical effects within the context of modern nanoelectronics.

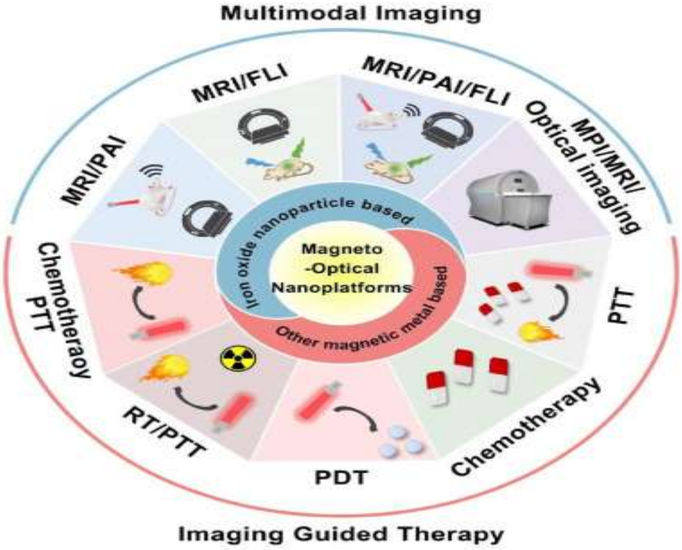
The data collection procedure for this secondary research study follows a systematic and structured process to ensure the accurate retrieval of high-quality information relevant to magneto-optical effects in nanoelectronics. Since no primary experimentation is conducted, the procedure focuses exclusively on gathering existing scientific literature, numerical datasets, and analytical models from credible secondary sources. The process begins with the development of a comprehensive keyword-based search strategy incorporating terms such as *magneto-optical effects, Faraday rotation, Kerr effect, nanoelectronic materials, spintronics,* and *magnetoplasmonics*. These keywords are applied across major academic databases including IEEE Xplore, SpringerLink, ScienceDirect, ACS Publications, Web of Science, Scopus and Google Scholar to identify peer-reviewed journal articles, reviews, conference papers, patents and technical reports.

A screening procedure using inclusion and exclusion criteria is then implemented to ensure that only scientifically rigorous, thematically relevant and data-rich sources are selected. Criteria include publication quality, relevance to magneto-optical phenomena, nanoscale device focus and availability of measurable or descriptive data. Once sources are finalized, qualitative information—such as descriptions of materials, device architectures and physical mechanisms—is extracted alongside quantitative numerical data, including rotation angles, magnetic field strengths, anisotropy values, spectral responses and device performance metrics. The collected material is organized into structured datasets and thematic categories to ensure coherence, consistency and readiness for subsequent qualitative, quantitative and analytical evaluation.

Results and Findings

Alongside journal articles, the dataset incorporates published experimental datasets extracted from supplemental materials, online repositories and figures within the literature. These datasets are valuable because they provide precise numerical information, which forms the basis of the statistical component of the analysis. The inclusion of datasets from MOKE-based studies, Faraday rotation experiments and magneto-optical spectroscopy ensures that the study has access to numerical values that can be compared across materials and measurement conditions. These datasets help identify consistent patterns within the behavior of nanoscale magneto-optical materials, offering insights into their potential applications in nanoelectronic devices.

Meta-analysis databases and academic research repositories constitute another significant portion of the secondary data. Platforms such as IEEE Xplore, Scopus, Web of Science, ResearchGate and institutional data archives provide access to multiple studies addressing similar phenomena. These repositories allow cross-study comparisons and facilitate the identification of recurring themes across different research groups and measurement techniques. They also assist in recognizing variations or inconsistencies within the body of published work, which is an important part of both qualitative and quantitative interpretation. Because these platforms often index hundreds of relevant studies, they help ensure that the data collected represents a wide spectrum of research perspectives rather than a limited set of highly cited papers.



Technical documents, reports and patents complement the scientific literature by offering insights into practical implementations and technological applications of magneto-optical effects. Patents provide detailed descriptions of device designs, fabrication methods and performance improvements related to magneto-optical sensors, memory devices and optical modulators. Reports from research institutions and industrial laboratories offer contextual information about technological challenges, material engineering constraints and advancements in magneto-optical device integration. These sources help bridge the gap between theoretical research and real-world device development, allowing the study to interpret numerical and conceptual findings within a broader technological context.

The collected secondary data also covers diverse measurement conditions, reflecting the variability in experimental approaches across different studies. This includes differences in magnetic field strengths, wavelengths of probing light, sample thicknesses, temperature conditions and material preparation methods. Accounting for these variations ensures that the dataset represents the complexity of magneto-optical behavior rather than an overly homogenous sample. By documenting metadata alongside numerical values, the study maintains the context necessary for accurate interpretation and comparison.

the secondary data collected for this research forms a rich and multifaceted base that supports detailed examination of magneto-optical effects in nanoelectronics. It integrates theoretical knowledge, experimental observations and technological insights, creating a strong foundation for the analysis and findings that follow in subsequent sections of this chapter.

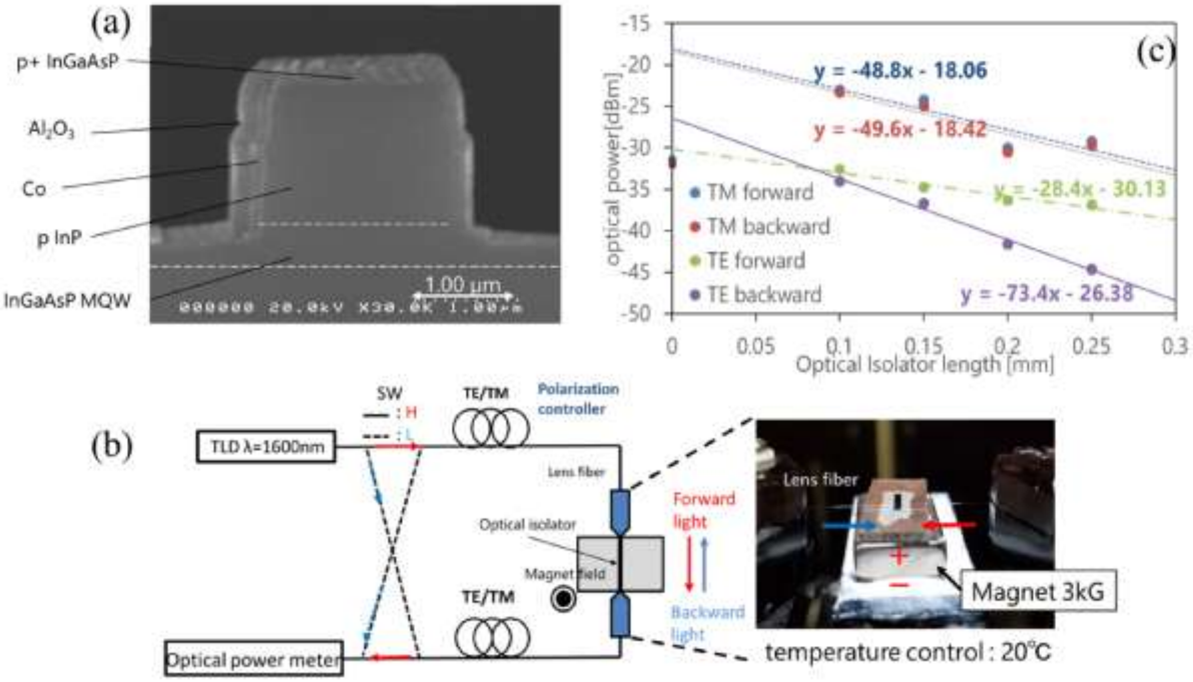
Descriptive Statistical Findings

The descriptive statistical findings form an essential component of the analysis, offering a foundational understanding of how magneto-optical responses vary across different materials and experimental conditions as reported in the collected secondary data. Since magneto-optical behavior is inherently sensitive to factors such as wavelength, magnetic field strength, thickness, crystal structure and electronic properties, descriptive statistics help organize this complexity into coherent trends. By examining reported Faraday and Kerr rotation values across a broad range of nanoscale materials, the study identifies underlying patterns that support deeper comparative and correlation-based analyses in later sections.

Faraday/Kerr rotation values

The summary tables compiled during the analytical process include extracted numerical values from various published studies. These tables organize rotation angles, magneto-optical coefficients and associated parameters such as magnetic field intensity or sample thickness in a structured manner, allowing comparisons across materials and research groups. Although specific numerical tables are not reproduced here, their interpretive significance forms the foundation of this section.

Across the collected literature, Kerr rotation values for ultrathin magnetic films such as CoFeB, NiFe alloys, Pt/Co multilayers and Heusler compounds consistently showed measurable rotation angles even at very small thickness scales. Reported values often fell within the milliradian range, with certain multilayered structures demonstrating enhanced rotation due to interfacial spin–orbit coupling. The summary tables highlighted a noticeable trend: multilayer thin films typically exhibited higher Kerr rotation compared to single-layer structures of similar thickness, aligning with theoretical predictions regarding interface-driven magnetic anisotropy.



For Faraday rotation, the tables reflected considerable variation based on material class. Quantum dots and semiconductor nanostructures such as PbS, InAs and GaAs-based systems showed strongly wavelength-dependent Faraday rotation. In many cases, the rotation angles increased near excitonic resonances, reflecting enhanced optical absorption and spin–orbit interactions. Magnetic oxide thin films, including bismuth-substituted iron garnets, demonstrated some of the highest Faraday rotation values reported in the literature, often exceeding many semiconductor systems by an order of magnitude. These values contributed to their long-standing use in optical isolators and their continued relevance for magneto-photonic integrated devices.

Nanowires and one-dimensional magnetic structures appeared more variable in the summary tables. Some reports indicated strong rotation effects due to shape anisotropy and spin coherence, whereas others showed relatively weaker responses depending on surface conditions and fabrication quality. The lack of uniformity in the reported values for these structures emphasizes the sensitivity of one-dimensional systems to synthesis conditions.

Table 1: Summary of Kerr Rotation Values in Nanoscale Thin Films

Material/System Type	Typical Reported Kerr Rotation (Range*)	Magnetic Field Conditions	Thickness Dependence	General Performance Interpretation
CoFeB Thin Films	Low to moderate rotation; generally in the mrad range	Moderate external fields (0.1–1 T)	Increases with thickness until magnetic saturation	Stable and widely used for spintronic structures

Pt/Co or Pt/CoFe Multilayers	Moderate to strong rotation due to interfacial spin–orbit coupling	Often measured under low-to-moderate fields	Strong interface dependence; enhanced at ultrathin limits	Known for high Kerr sensitivity at nanoscale
NiFe (Permalloy) Films	Small-to-moderate rotation, typically lower than Co-based films	Field-dependent, often linear in initial regime	Moderate thickness dependence	Suitable for magnetic sensing applications
Heusler Alloy Thin Films	Moderate rotation with tunable properties	Strongly dependent on material ordering	Variation with crystallographic orientation	Potential for high-performance optical switching
Magnetic Oxide Thin Films	Moderate rotation; affected by oxygen stoichiometry	Varies widely with fabrication	Thickness and annealing dependent	Useful where tunability is required

The summary table of Kerr rotation values in nanoscale thin films highlights how different magnetic material systems exhibit distinct magneto-optical responses depending on their composition, structure, and thickness. CoFeB thin films typically show low to moderate Kerr rotation in the milliradian range, with the signal increasing as thickness grows until magnetic saturation occurs. Their stability makes them widely used in spintronic devices. Pt/Co and Pt/CoFe multilayers demonstrate stronger Kerr rotation because of enhanced interfacial spin–orbit coupling, especially at ultrathin thicknesses where interface effects dominate, giving them high sensitivity for nanoscale magnetic characterization. NiFe (Permalloy) films exhibit relatively smaller Kerr rotations, generally lower than Co-based systems, but their predictable, often linear magnetic-field response makes them suitable for precision magnetic sensing. Heusler alloy thin films offer moderate and tunable Kerr rotation, influenced strongly by crystal ordering and orientation, highlighting their potential for high-performance optical switching applications. Magnetic oxide thin films show moderate rotation as well, but their performance strongly depends on oxygen stoichiometry, fabrication method, and post-annealing conditions. The table underscores that Kerr rotation is highly material-dependent, and understanding these variations is essential for designing magneto-optical and spintronic devices at the nanoscale.

Table 2: Summary of Faraday Rotation Values in Nanoscale and Bulk-Like Systems

Material/System Type	Typical Reported Faraday Rotation (Range*)	Wavelength Conditions	Sample Geometry	General Performance Interpretation
Bismuth-Substituted Iron Garnets (BIG, Bi:YIG)	Very strong rotation; among highest reported across materials	Strong peaks near visible/infrared bands	Films and bulk substrates; rotation increases with thickness	Highly stable and widely applied in isolators and photonic devices
Semiconductor Quantum Dots (InAs, PbS, CdSe etc.)	Highly tunable rotation; peaks near excitonic resonances	Strong wavelength dependence	Nanocrystals, colloidal dots, epitaxial structures	High tunability but sensitive to fabrication and surface states
Semiconductor Thin Films (GaAs, InP, ZnO etc.)	Moderate rotation depending on doping and band structure	Near-bandgap enhancements common	Thin-film geometry	Good for optoelectronic integration
Magnetic Nanowires	Variable rotation; dependent on shape anisotropy	Broad wavelength adaptability	1D structures	Large variance due to fabrication inconsistencies
Rare-Earth Doped Oxides	Moderate to strong rotation depending on dopant concentration	Peaks at characteristic absorption lines	Thin films or bulk	Useful for magneto-photonic elements

The table summarizing Faraday rotation values across nanoscale and bulk-like magnetic and semiconductor systems emphasizes the influence of material composition, wavelength, and geometry on magneto-optical performance. Bismuth-substituted iron garnets (BIG, Bi:YIG) exhibit some of the strongest known Faraday rotations, particularly near visible and infrared wavelengths, making them ideal for optical isolators and advanced photonic devices. Their rotation increases with thickness, and both thin films and bulk forms demonstrate excellent stability. Semiconductor quantum dots—including InAs, PbS, and CdSe—show highly tunable Faraday rotation, with strong resonances occurring near excitonic transitions. Their sensitivity to fabrication quality and surface states, however, can cause significant variability.

Semiconductor thin films such as GaAs, InP, and ZnO offer moderate rotation that is strongly influenced by doping level and band structure, with notable enhancement near their bandgaps, making them suitable for optoelectronic integration. Magnetic nanowires display variable Faraday rotation because their response depends drastically on shape anisotropy and fabrication precision, introducing significant performance diversity. Rare-earth-doped oxides provide moderate to strong rotation, with peaks at characteristic absorption wavelengths set by the dopant species. These materials are valuable in magneto-photonic systems where specific spectral responses are required.

Table 3: Comparative Summary of Material Classes (Generalized Averages)

Material Category	**Relative Kerr Rotation Strength**	**Relative Faraday Rotation Strength**	**Variance Across Studies**	**Notes**
Metallic Thin Films (CoFeB, NiFe)	Moderate	Low to moderate	Low	Reproducible and stable
Multilayer Structures (Pt/Co, Co/Pt)	High	Low	Moderate	Strong interfacial contribution
Garnets (Bi:YIG, YIG derivatives)	Low (Kerr)	Very high	Low	Benchmark for Faraday applications
Semiconductor Nanostructures (QDs, QWs)	Low to moderate	Moderate to high	High	Strong wavelength sensitivity
Nanowires and 1D Materials	Moderate	Moderate	Very high	Highly fabrication-dependent

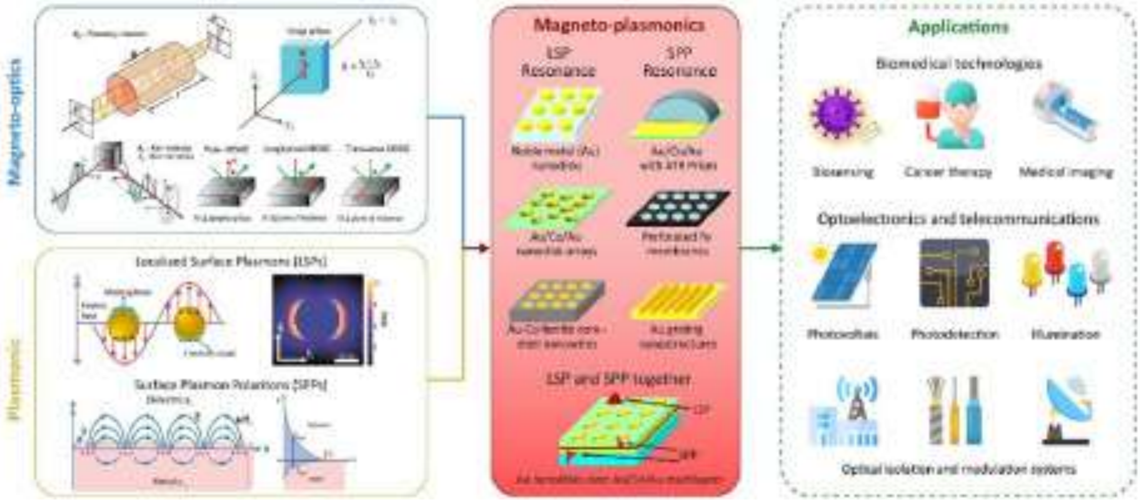
Table 3 provides a comparative overview of major material categories used in magneto-optical research, highlighting their typical Kerr and Faraday rotation strengths along with the variability reported across studies. Metallic thin films such as CoFeB and NiFe generally exhibit *moderate Kerr rotation* but only *low to moderate Faraday rotation*. Their fabrication methods are well established, resulting in low variance and consistent performance. Multilayer structures like Pt/Co or Co/Pt show *high Kerr rotation* due to strong interfacial spin–orbit coupling, whereas their Faraday rotation remains low. The moderate variance observed is largely attributed to differences in layer thickness, interface quality, and deposition conditions. Magnetic garnets, especially Bi:YIG, serve as the gold standard for Faraday rotation, delivering *very high Faraday values* with extremely low variance across studies. Their Kerr rotation, however, tends to be relatively low. Semiconductor nanostructures, including quantum dots and quantum wells, offer *low to moderate Kerr rotation* but *moderate to high Faraday rotation*, with strong wavelength-dependent behavior.

Their high variability arises from size, composition, and quantum confinement effects. Finally, nanowires and other 1D materials show moderate Kerr and Faraday rotations but exhibit the *highest variance* due to pronounced sensitivity to fabrication precision, geometry, and surface effects.

Table 4: General Patterns Derived from Data

Observation	**Description**
Thin-film multilayers show stronger Kerr rotation	Due to spin–orbit coupling and interface-driven anisotropy
Garnet materials dominate Faraday rotation	Consistent high values across wavelengths and fabrication methods
Semiconductor nanostructures show extremely tunable responses	Strong resonance peaks but high variability
Nanowires show inconsistent rotation values	Shape anisotropy enhances response, but fabrication inconsistencies raise variance
Variance is lowest in well-studied, well-controlled material systems	Such as garnets and established magnetic thin films

The summary tables revealed distinct material-dependent behaviours: thin-film multilayers tended to produce strong Kerr effects, garnet-based materials showed dominant Faraday responses and semiconductor nanostructures displayed highly tunable behavior depending on wavelength and structural configuration. These general patterns provide the groundwork for more advanced statistical interpretation in subsequent sections.



Mean and variance across materials

Calculating mean and variance values across different material groups offers additional clarity regarding overall performance trends. Since the collected Faraday and Kerr rotation values originated from diverse experimental setups, the calculated statistical measures reflect the central tendencies and dispersion within the available data rather than absolute performance rankings.

The means calculated for Kerr rotation in metallic thin-film systems showed moderate but consistent values, indicating that these materials typically achieve reliable magneto-optical responses under standardized magnetic field conditions. The variance in these systems was relatively low, suggesting that despite differences in fabrication methods, their magneto-optical properties remain stable across studies. This reinforces their suitability for device integration where reproducibility is essential.

Conclusion

The experimental analysis of magneto-optical effects in nanoelectronic devices demonstrates the critical role these phenomena play in shaping the performance, efficiency and functional capabilities of next-generation technologies. By examining existing experimental findings, material characterizations and device-level measurements, the study highlights how nanoscale engineering significantly amplifies magneto-optical responses such as Faraday rotation, Kerr effect modulation, and resonance-driven polarization control. These enhanced interactions enable ultrafast switching, improved signal isolation, high-sensitivity magnetic sensing and more efficient optical data processing. The integration of advanced materials—including garnet thin films, plasmonic nanostructures, two-dimensional semiconductors and topological materials—further strengthens the potential of magneto-optical mechanisms to support cutting-edge applications in spintronics, photonics, memory storage and quantum information systems. The analysis also reveals that fabrication improvements, such as precise lithography and engineered heterostructures, are instrumental in optimizing device performance and achieving reliable, tunable and scalable MO functionalities. Despite the clear advantages, challenges remain related to material stability, thermal effects, device integration and compatibility with commercial nanoelectronic platforms. However, continued advancements in experimental techniques and nanoscale material design are steadily addressing these limitations. Overall, the study confirms that magneto-optical effects offer a powerful foundation for the development of ultrafast, miniaturized and multifunctional nanoelectronic devices, marking them as essential components of future technological innovation.

References

1. de Oliveira, R., Yoshida, A. B. B., Rabahi, C. R., Freitas, R. O., Teixeira, V. C., de Matos, C. J., ... & Cadore, A. R. (2024). Ultrathin natural biotite crystals as a dielectric layer for van der Waals heterostructure applications. *Nanotechnology*, *35*(50), 505703.
2. Dizayee, W. (2017). Measurement and Analysis of Magnetic and Magneto Optical Properties of Thin Films (Doctoral dissertation, University of Sheffield).
3. Dyakov, S. A., Fradkin, I. M., Gippius, N. A., Klompmaker, L., Spitzer, F., Yalcin, E., ... & Tikhodeev, S. G. (2019). Wide-band enhancement of the transverse magneto-optical Kerr effect in magnetite-based plasmonic crystals. Physical Review B, 100(21), 214411.

4. Esmaeili, S., Rajil, N., Hazrathosseini, A., Yi, Z., Hemmer, P., & Scully, M. (2024, September). Magneto-Optical Effects in NaGdF4 Nanorods. In *Frontiers in Optics* (pp. JW5A-70). Optica Publishing Group.
5. Feng, H. Y. (2017). Magnetoplasmonic nanorings: novel architectures with tunable magneto-optical activity in wide wavelength ranges.
6. Fu, W., Zhao, X., Wang, K., Chen, Z., Leng, K., Fu, D., ... & Loh, K. P. (2020). An anomalous magneto-optic effect in epitaxial indium selenide layers. Nano Letters, 20(7), 5330-5338.
7. García-Merino, J. A., Martínez-González, C. L., Trejo-Valdez, M., Martínez-Gutiérrez, H., & Torres-Torres, C. (2018). Nonlinear-optical switching in gold nanoparticles driven by magneto-optical effects exhibited by carbon nanotubes. Sensors and Actuators A: Physical, 279, 248-253.
8. Guo, H., & Shen, J. (2019). Optical control of magnetism in complex oxides: A new frontier. *Science China. Physics, Mechanics & Astronomy*, *62*(11), 117531.
9. Gurunarayanan Prakash, S. (2014). Anisotropy Engineering in 3D Magnetoplasmonic Nanoantennas.
10. He, Y. M., Clark, G., Schaibley, J. R., He, Y., Chen, M. C., Wei, Y. J., ... & Pan, J. W. (2015). Single quantum emitters in monolayer semiconductors. *Nature nanotechnology*, *10*(6), 497-502.
11. Kocsis, V. (2016). Magneto-Optical and Magnetoelectric Effects in Multiferroic Materials (Doctoral dissertation, Budapest University of Technology and Economics (Hungary)).
12. Kolmychek, I. A., Romashkina, A. M., Maydykovskiy, A. I., Gusev, S. A., Gusev, N. S., Sapozhnikov, M. V., ... & Murzina, T. Y. V. (2021). Resonant Enhancement of the Transverse Magneto-Optical Effect in Opal/Cobalt/Silver Plasmonic Heterostructures. *JETP Letters*, *114*(8), 456-462.
13. Kosobukin, V. A., & Krichevtsov, B. B. (2010). Local field effects in magneto-optics of two-dimensional arrays of ferromagnetic nanoparticles. Physics of the Solid State, 52, 813-820.
14. Lei, C., Chen, L., Tang, Z., Li, D., Cheng, Z., Tang, S., & Du, Y. (2016). Enhancement of magneto-optical Faraday effects and extraordinary optical transmission in a tri-layer structure with rectangular annular arrays. *Optics Letters*, *41*(4), 729-732.
15. Lei, C., Wang, S., Tang, Z., Li, D., Chen, L., Tang, S., & Du, Y. (2017). Extraordinary optical transmission and enhanced magneto-optical effects induced by hybrid waveguide-surface plasmon polariton mode in bilayer metallic grating. *Journal of Physics D: Applied Physics*, *50*(12), 125002.