Горобець О.Ю., Куліш В.В., Єрьомін С.І.
Національний технічний університет України «Київський політехнічний інститут імені Ігоря Сікорського», Берестейський проспект, 37, Київ, email:gorobets.oksana@gmail.com

DEVELOPMENT OF THEORETICAL RESEARCH ON MAGNON–PLASMON–POLARITONS WORLDWIDE

Анотація. Проаналізовано етапи розвитку концепції магнон-плазмонних поляритонів (МПП) у світовій науці, визначення ключових теоретичних та експериментальних досягнень і оцінка потенціалу цих збуджень у сучасних фотонних та квантових технологіях. Висвітлено історію досліджень поверхневих плазмон-поляритонів, та становлення магноніки, що у поєднанні сформувало основу для появи МПП. Отримано результати, що свідчать про зростання міждисциплінарного інтересу до цих збуджень з огляду на їх перспективи у мініатюризації, керованості та енергоефективності високочастотних пристроїв.

Abstract. The stages of development of the concept of magnon-plasmon polaritons (MPPs) in global science have been analyzed, including the identification of foundational theoretical and experimental works and the assessment of their potential use in emerging photonic and quantum systems. The history of research on surface plasmon polaritons and spin waves as the building blocks of MPPs has also been reviewed. The results indicate a growing interdisciplinary interest in MPPs, driven by the demand for compact, tunable, and energy-efficient high-frequency components.

Ключові слова: *поверхнева хвиля, магнон-плазмонний поляритон, динаміка намагнічування, колективне електронне збудження, спінова хвиля, магнон, плазмон, гібридна хвиля, феромагнетик.*

Keywords: *surface wave, magnon-plasmon polariton, magnetization dynamics, collective electron excitation, spin wave, magnon, plasmon, hybrid wave, ferromagnet.*

Magnon-plasmon polaritons (MPPs) are quanta of hybrid waves that arise from electromagnetic waves' interaction with free electron oscillations in metals and magnetostatic modes in magneto-plasmonic structures. MPPs exhibit advantageous properties such as non-reciprocity, low-loss propagation, and strong field localization, making them excellent candidates for THz-range applications. In particular, MPPs in layered and structural materials are promising for next-generation quantum devices, sensors, and reconfigurable circuits.

This report aims to review key milestones in the development of MPPs, identify landmark theoretical and experimental breakthroughs, and evaluate their potential in modern photonic and quantum technologies.

The study of surface electromagnetic waves (SEWs) has a long and rich history, beginning with the pioneering work of Sommerfeld [1] and Zenneck [2], who described the propagation of waves along conducting interfaces. These foundational studies led to the emergence of surface plasmon polaritons (SPPs), resulting from the coupling between electromagnetic fields and free electron oscillations at metal-dielectric boundaries. Over the decades, SPPs became essential for nanophotonics, biosensing, and optical circuitry due to their strong field confinement and spectral tunability.

In parallel, another field – magnonics – gained traction. Initiated by Bloch's theory of spin waves in 1930 [3] and reinforced by experimental evidence in the 1960s [4], magnonics explores the collective excitations of spin in magnetically ordered media. Spin waves and their quanta, magnons, offer low-energy information transport mechanisms, inspiring new generations of logic and memory devices.

The convergence of plasmonics and magnonics has led to the recent development of magnon-plasmon polaritons (MPPs) – a novel class of hybrid excitations combining charge and spin dynamics through electromagnetic coupling. While the theoretical foundation for hybrid polaritons was laid in the 1970s by Mills and Burstein [5], the MPP concept gained significant attention in the last decade [6] with the advancement of magneto-plasmonic structures.

The aim of the report - to review key milestones in developing MPPs, identify landmark theoretical and experimental breakthroughs, and evaluate their potential in modern photonic and quantum technologies – has been reached. The findings underscore a growing interdisciplinary interest in MPPs, driven by the need for miniaturized, tunable, and energy-efficient high-frequency devices.

REFERENCES

[1] Sommerfeld, A. (1899). Ueber die Fortpflanzung elektrodynamischer Wellen längs eines Drahtes. *Annalen der Physik, 2*(3), 233–290. https://doi.org/10.1002/andp.18993030202

[2] Zenneck, J. (1907). Über die Fortpflanzung ebener elektromagnetischer Wellen längs einer ebenen Leiterfläche und ihre Beziehung zur drahtlosen Telegraphie. *Annalen der Physik, 1*(8), 846–866. https://doi.org/10.1002/andp.19073281003

[3] Bloch, F. (1930). Zur Theorie des Ferromagnetismus. *Zeitschrift für Physik, 61*(3–4), 206–219.
[4] Damon, R. W., & Van de Vaart, H. J. (1965). Propagation of magnetostatic spin waves at microwave frequencies in normally magnetized disk. *Journal of Applied Physics*, *36*(10), 3453–3459.
[5] Mills, D. L., & Burstein, E. (1974). Polaritons: The electromagnetic modes of media. *Reports on Progress in Physics*, *37*(7), 817–926. https://doi.org/10.1088/0034-4885/37/7/001
[6] Li, Y., Zhang, W., Tyberkevych, V., Kwok, W. K., Hoffmann, A., & Novosad, V. (2020). Hybrid magnonics: Physics, circuits, and applications for coherent information processing. *Journal of Applied Physics*, *128*(13). https://doi.org/10.1063/5.0025845