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Photonic Data Centers: Advancing Energy Efficiency and Speed in Next-Generation Cloud Infrastructure

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The growing demand for high-performance cloud computing has intensified the need for faster, more energy-efficient data centres. Photonic data centres, leveraging optical computing and fibre-optic communication, offer a transformative solution by significantly reducing energy consumption while increasing data transmission speeds. Unlike traditional electronic-based data centres, photonic architectures minimize latency, heat dissipation, and power usage, making them ideal for scalable and sustainable cloud infrastructure. This paper explores the role of silicon photonics, optical interconnects, and quantum photonic processors in enhancing computational efficiency, bandwidth, and AI-driven workloads. Additionally, we address challenges such as integration complexities, cost constraints, and the need for new optical networking protocols. As the demand for AI, big data, and real-time analytics grows, photonic data centres emerge as a key enabler of next-generation cloud computing, driving innovation toward ultra-fast, low-power, and environmentally sustainable digital infrastructure.