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**Quantum enhancement in the limit of detection measurement of a phase-based plasmonic biosensor including loss**

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The Human Immunodeficiency Virus Type 1 (HIV-1) stands as one of the most significant viral pathogens that have impacted human health globally.<sup>1</sup> It is the primary cause of HIV infection, leading to Acquired Immunodeficiency Syndrome (AIDS), a condition that has posed a formidable challenge to the medical and scientific communities since its emergence in the late 20th century.<sup>2</sup> HIV-1 is characterized by its ability to attack the body's immune system, specifically targeting CD4<sup>+</sup> T cells, which play a crucial role in orchestrating the body's immune response.<sup>3</sup> As the virus replicates and depletes these cells, it progressively weakens the immune system, leaving the body vulnerable to a range of opportunistic infections and diseases that define the late stage of the infection, known as AIDS. Distinguished from HIV-2, which is less transmissible and prevalent primarily in West Africa, HIV-1 is the more virulent and widespread strain of the virus.<sup>4</sup> It exhibits a high genetic variability, resulting in numerous subtypes and recombinant forms that have significant implications for vaccine development, treatment, and the global epidemiology of the disease.<sup>5</sup> Since its identification in the early 1980s, HIV-1 has been a focal point of extensive research. This research has led to significant advancements in understanding the virus's biology, transmission mechanisms, and pathogenesis. These advancements have, in turn, informed effective strategies for prevention, diagnosis, and treatment, most notably the development of antiretroviral therapy (ART), which has transformed HIV-1 infection from a fatal diagnosis into a manageable chronic condition for many.<sup>6</sup> However, despite these strides, HIV-1 continues to be a major public health issue, with millions of individuals worldwide living with the virus and facing associated challenges, including medical, social, and economic burdens. The ongoing quest for an effective vaccine and cure, coupled with efforts to reduce stigma and improve access to prevention and treatment services, remains at the forefront of the global health agenda in addressing the HIV-1 pandemic.<sup>7–9</sup> Optical biosensors, particularly those based on surface plasmon resonance (SPR), have emerged as powerful tools in the detection and study of HIV-1.<sup>10, 11</sup> These biosensors offer several advantages in the field of virology and immunology, particularly in terms of sensitivity, specificity, and real-time analysis.