HAMAMATSU
PHOTON IS OUR BUSINESS

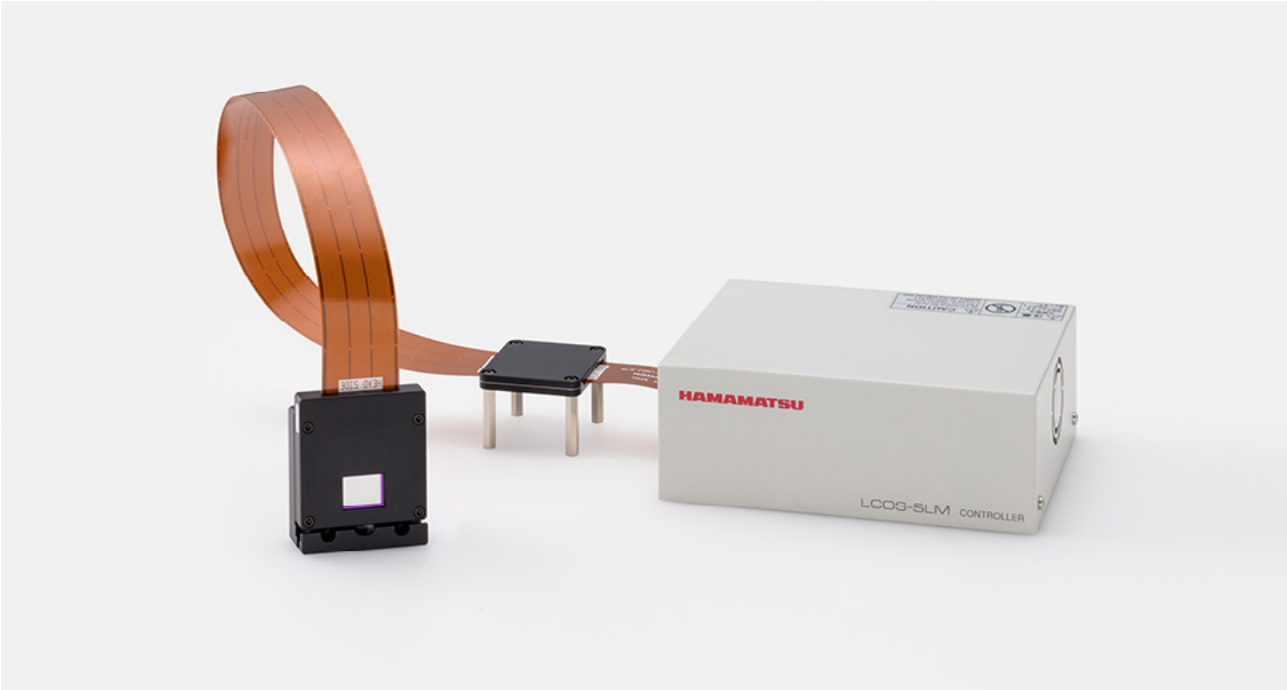
Enhancing Precision for Quantum and Manufacturing Applications

Hamamatsu Photonics has been continuously working on solutions to reduce the phase noise in its liquid crystal on silicon spatial light modulators [1], which are critical for applications such as quantum computing, quantum key distribution, and high-precision manufacturing. The latest line of LCOS-SLMs from Hamamatsu is equipped with a low-noise mode, limiting phase ripples to below 4 mrad (peak-to-peak), which is two orders of magnitude lower than some of the LCOS-SLMs currently available in the market.

Origin of jitter in LCOS-SLMs

In LCOS-SLMs, the phase retardation at a given pixel is controlled by the orientation of liquid crystal (LC) molecules, which is set by the drive voltage applied to the electrodes in that pixel [2]. For a faster response, LCOS-SLMs from Hamamatsu are driven by an AC voltage whose magnitude at a pixel depends on the desired phase retardation [3]. The drive voltage frequency is higher than the response time of the LC molecules to the driving electric field. As a result, during each cycle of the AC drive voltage, the LC molecules twitch momentarily without changing their average orientation over the cycle. However, this twitching of LC molecules results in small shifts or jitters in the beam pattern [4], which are undesirable in certain applications.

In comparison, some manufacturers use pulse-width modulation (PWM) to drive LC molecules [5]. In PWM, the magnitude and frequency of the drive voltage remain constant, but the duty cycle changes according to the desired phase retardation. This mechanism also results in the twitching of LC molecules, causing jitters in the beam pattern [4].



Hamamatsu Photonics' X15213 Series LCOS-SLM.

Significance of jitter in certain beam shaping applications

High Precision Manufacturing

Laser material processing applications, which include marking and high-precision manufacturing, can improve throughput by using beam-shaping solutions based on LCOS-SLMs. However, the jitter in the beam pattern can sometimes adversely affect the quality of the output.

Quantum Computing and Quantum Key Distribution

In atom trap-based quantum computing, LCOS-SLMs are used to create laser spot arrays that act as potential wells to trap atoms. Jitter can affect the steepness and positional accuracy of the potential wells. This can result in unstable atom traps, inaccurate quantum state readouts and limited scalability of the quantum computer.

Similarly in quantum key distribution (QKD), LCOS-SLMs are used to encode quantum keys in the form of beam patterns and then transfer them via optical networks. Phase noise directly affects the integrity of the quantum keys, the distance over which they can be transported and can potentially make them susceptible to interception by third parties. Certain QKD protocols use interference between keys and jitter, which can reduce the readability of interference patterns. Finally, phase noise also increases the burden of error correction measures, decreasing overall efficiency.

Low noise mode of LCOS-SLMs from Hamamatsu

Hamamatsu's LCOS-SLMs are known for their low-phase noise, resulting from the twitching of LC molecules. Even at the maximum magnitude of drive voltage, the peak-to-peak phase noise is as low as 8 mrad (figure).

Engineers at Hamamatsu have developed a low noise mode to further suppress this phase noise. Consequently, the fluctuation in phase retardation is suppressed by 60% (see figure below) and the peak-to-peak value of the phase fluctuations is only a few mrad which is extremely low for LCOS-SLMs.

The low-noise mode of Hamamatsu's LCOS-SLMs effectively addresses these challenges without requiring any changes in the product integration. However, the low-noise mode has one drawback: a relatively slower response time of LC molecules. In applications where beam shaping accuracy and stability take precedence over high refresh rates, the innovative low-phase noise feature of Hamamatsu's LCOS-SLMs is a compelling solution.

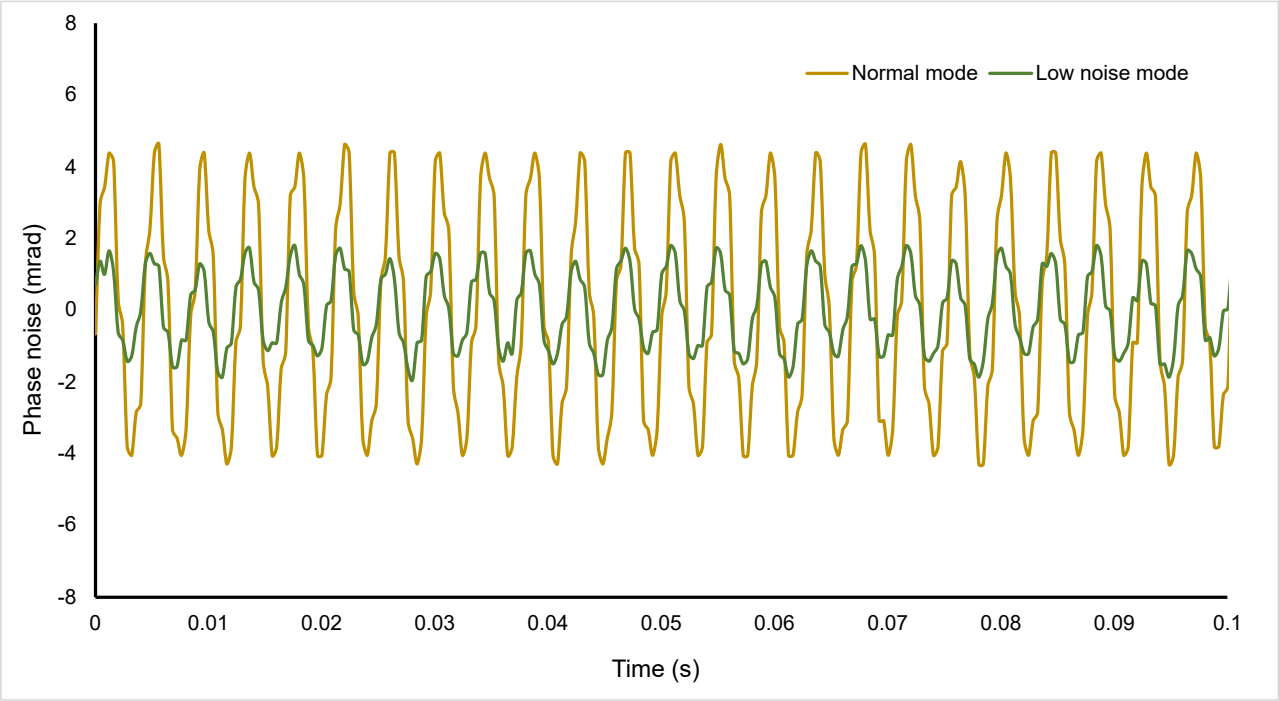


Figure: Peak-to-peak phase noise due to fluctuations of LC molecules in normal and low noise modes of Hamamatsu's LCOS-SLMs.

The quest for stability in optical applications is not merely a technical challenge. Industries rely on precision and accuracy for their success. The low-noise mode in LCOS-SLMs is designed to assist engineers in their pursuit of accuracy, and consequently accelerate development of applications like high precision manufacturing, quantum computing and communications. In our intricately connected world, every detail matters for a future defined by precision and reliability.

For more information visit: www.hamamatsu.com or email info@hamamatsu.eu

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