

PIPU WHITEPAPER II

PIPU™ Experimental Results and Validation

Physics-Native Photonic Intelligence for
Dynamical Complexity in Real-World
Financial Market Fluctuations, Inference,
and Autonomous Prediction



REAL-WORLD
FINANCIAL DATA



PHOTONIC
COMPUTING



AUTONOMOUS
INFERENCE



MULTI-DATASET
EVALUATION

EXPERIMENTAL
EVIDENCE
TOWARD PRACTICAL
PHOTONIC COMPUTE

SEPTEMBER 2026

QUANTLASE RESEARCH
AND DEVELOPMENT CENTER
QRDC

FOREWORD AND AUTHORS NOTE

From Photonic Computing Research to Real-World Applications

Evidence, Perspective and the Path Ahead

PIPU represents a focused effort to explore how physics-native photonic computing can contribute to real-world AI applications. This whitepaper presents our latest experimental results, key learnings and future outlook, grounded in rigorous research and a practical view of potential impact.

FOREWORD



Dr. Pramod Kumar, Ph.D.
(Laser Tech)
Director of Research, QRDC

The rapid growth of AI is increasing the demand for more capable and efficient computation. Photonics offers a compelling research direction by harnessing the unique properties of light to process information through physical dynamics.

With PIPU, we investigate how coherent propagation, nonlinear effects and feedback in optical systems can be utilised for computation. Our goal is to establish, through systematic experimentation, where such dynamics can deliver measurable computational benefits and under what conditions they can be scaled into practical photonic computing infrastructure.

This work is a step in a longer research journey to evaluate the scientific potential, practical feasibility and real-world value of photonic computing for AI applications.

AUTHORS' NOTE



Dr. Salman Abdullah
Product Director, QRDC

Turning advanced photonic computing research into real-world impact requires more than technical development. It requires translating complex and abstract science and research frameworks into clear, structured narratives that can be understood by investors, industry partners and the wider public.

The focus of this work is to bridge the gap between cutting-edge research and practical applications by developing a coherent platform vision, positioning real-world value, and creating accessible explanations of the technology's significance, capabilities and potential market impact.

Through engagement with international forums, industry stakeholders and the global research community, this work aims to build strategic partnerships, accelerate the path toward real-world deployment, and establish a broader ecosystem for physics-native photonic computing.



OUR SHARED COMMITMENT

We are committed to advancing photonic computing through open research, rigorous validation and real-world collaboration, with the goal of delivering practical, high-value applications for industry and society.

A Platform Positioning Statement for Real-World Impact

PIPU: Enabling Exploratory Research, Collaboration and Future Innovation

PIPU is an open research platform for exploring physics-native photonic computing and real-world applications. This whitepaper presents our methodologies, experimental results and analysis with full transparency. All datasets, raw data files, experimental images and supplementary materials are publicly available through the [open-access repository on Zenodo](#), enabling independent examination, reproduction and further research.

Our objective is to advance the field through rigorous, open and collaborative research. No claims of superiority are made. Instead, we present a credible, extensible and practical platform that can serve as a foundation for the research and industry community to build upon, validate and explore future possibilities.

Dr. Salman Abdullah

Product Director
QuantLase Research and Development Center

PIPU™ Experimental Results and Validation

Physics-Native Photonic Intelligence for Dynamical Complexity in Real-World Financial Market Fluctuations, Inference, and Autonomous Prediction

Multi-Dataset Evaluation Using a Physics-Native Photonic Computing Platform

FROM WHITEPAPER I TO WHITEPAPER II

Our first whitepaper introduced the Photonic Intelligence Processing Unit (PIPU), demonstrating an experimentally validated photonic computing platform based on nonlinear optical dynamics, closed-loop operation and an edge-of-chaos regime for temporal inference.

This second whitepaper focuses on experimental results obtained using multiple real-world financial datasets, evaluating the autonomous prediction capability of the same physical PIPU platform beyond the observed data window.

KEY OBJECTIVE

Can a physics-native photonic computing system operate autonomously on real-world financial market fluctuations and provide useful forward inference beyond the observed window across multiple independent datasets?

- Evaluate performance on diverse real-world financial datasets
- Demonstrate autonomous prediction beyond the test window
- Compare with AI and GPU baselines
- Analyse cross-dataset behaviour
- Establish path toward a managed PIPU compute service



PIPU experimental platform (SLM-optical propagation - detection - feedback)

WHY 2026?

The year 2026 represents the most recent and current market environment, allowing us to validate the PIPU platform on the latest real-world data. This demonstrates the model's ability to capture current market dynamics and maintain robust autonomous inference performance in a contemporary, evolving financial landscape.

DATASETS EVALUATED



Multiple real-world financial market datasets covering different sectors and market behaviours.

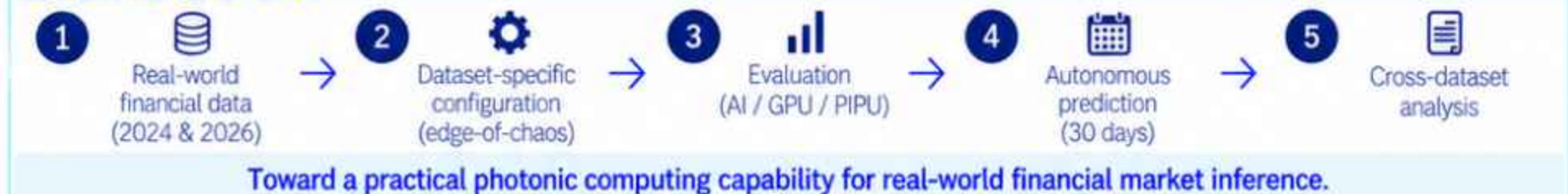
WHY 2024?

The year 2024 was selected as a post-COVID normalisation period. During this time, major financial markets showed meaningful temporal variation as investors adapted to the new normal, and the rapid growth of the AI sector added further dynamics. This provided a challenging and realistic test window for nonlinear temporal inference across diverse companies and sectors.

COMPARISON METHODS

 Actual Observed market time-series data used as the reference against which the prediction outputs are compared.	 PIPU + GPU Prediction Prediction generated using the physical PIPU experiment, with GPU-based electronic interface, data handling and control. Nonlinear photonic transformation is performed by the PIPU platform.	 AI Prediction Output from the advanced time-series machine-learning comparator used for short-horizon prediction. It operates as one benchmark to evaluate forecast trend magnitude and should not be interpreted as equivalent to the autonomous PIPU model.	 GPU Prediction Numerical simulation of the PIPU dynamical model executed entirely on a GPU. This represents a computational counterpart to the physical PIPU system and is not the desired output mode for autonomous inference.
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EXPERIMENTAL FLOW



EXPERIMENTAL RESULTS I (2026)

Financial Market Fluctuation Inference and Autonomous Prediction (Set 1)

Observed vs Predicted Performance Across Four Representative Datasets (2026)

The latest validation campaign evaluates the PIPU platform using real-world financial-market datasets from April to September 2026, followed by a 30-day autonomous inference regime. The results demonstrate the ability of the physical PIPU + GPU framework to track market dynamics and maintain a coherent autonomous trajectory.

SUPPORTING DATA
Open Access on Zenodo

Dataset: “PIPU Autonomous Prediction Training and Inference Datasets for Whitepaper”

Supporting experimental data have been made openly available on Zenodo to support transparency, reproducibility and independent examination.

COMPARISON METHODS

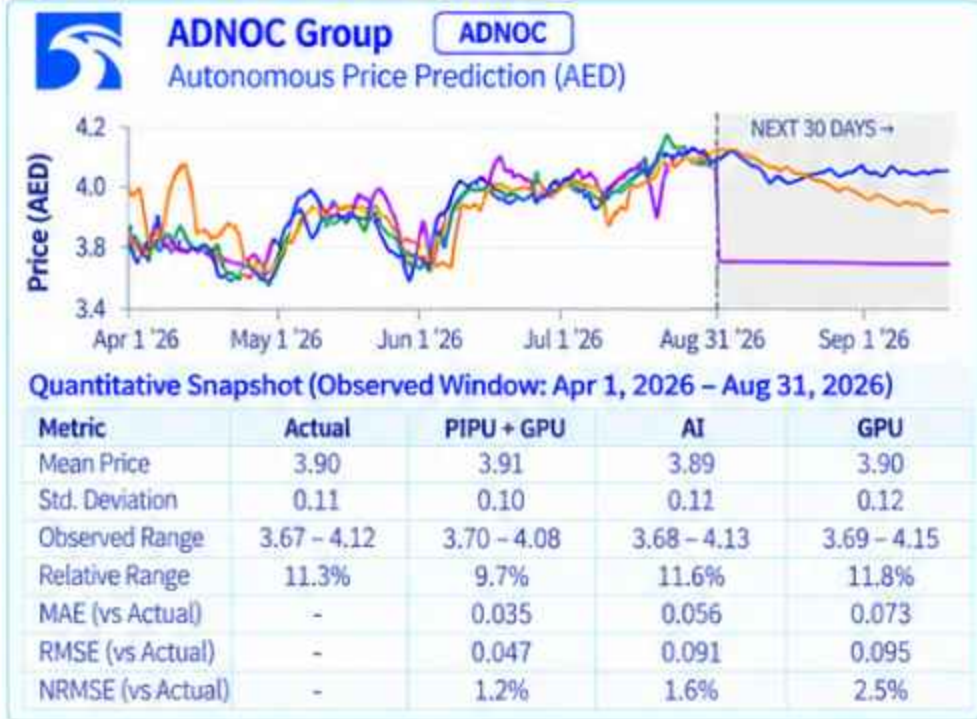
- Actual

Observed market time-series data used as the reference against which the prediction outputs are compared.
- PIPU + GPU Prediction

Prediction generated using the physical PIPU experiment, with GPU-based electronic interface, data handling and control. Nonlinear photonic transformation is performed by the PIPU platform.
- AI Prediction

Advanced time-series machine-learning comparator used for short-horizon prediction. Operates in one-step-ahead mode without seeing future values.
- GPU Prediction

Numerical simulation of the PIPU dynamical equations executed entirely on a GPU. Represents a computational baseline to the physical PIPU system.



Results and Observations (2026 Validation, Set 1)

- 1

Dataset Characteristics

The four datasets exhibit diverse behaviour in 2026. Amazon and Apple show broader price ranges and higher volatility. ADNOC displays moderate fluctuations, while FAB remains relatively stable with lower variance. This provides a useful set of real-world test cases across different sectors and market conditions.
- 2

Observed-Window Performance

Across the four datasets, the PIPU + GPU framework achieves lower error than the AI and GPU baselines in terms of both MAE and RMSE. The level of improvement varies by dataset, with the closest agreement observed for ADNOC and FAB, and larger absolute amazon and Apple. The results indicate a consistent tracking of trend and local fluctuations in the observed window.
- 3

Autonomous Inference (Next 30 Days)

In the autonomous phase, PIPU + GPU maintains a coherent trajectory for all four datasets. For ADNOC and FAB the trajectory remains within a similar operating range. For Amazon and Apple, the autonomous trajectory extends the recent trend direction. The GPU-only, while the AI comparator operates in a one-step-ahead testing mode and is not designed for autonomous rollout.
- 4

Key Takeaways

The 2026 results demonstrate that the physical PIPU platform can provide real-world financial market dynamics and maintain a coherent autonomous trajectory across diverse datasets. Performance varies with dataset characteristics, highlighting the importance of broader validation and further evaluation.

EXPERIMENTAL RESULTS II (2026)

Financial Market Fluctuation Inference and Autonomous Prediction (Set 2)

Observed vs Predicted Performance Across Three Additional Datasets (2026)

The 2026 validation campaign evaluates the PIPU platform using three additional real-world financial-market datasets. These results further demonstrate the ability of the physical PIPU + GPU framework to track market dynamics and maintain coherent autonomous predictions across different sectors, currencies and volatility regimes.

 **SUPPORTING DATA**
Open Access on Zenodo

Dataset: “PIPU Autonomous Prediction Training and Inference Datasets for Whitepaper”

Supporting experimental data have been made openly available on Zenodo to support transparency, reproducibility and independent examination.

COMPARISON METHODS

 **Actual**
Observed market time-series data used as the reference against which the prediction outputs are compared.

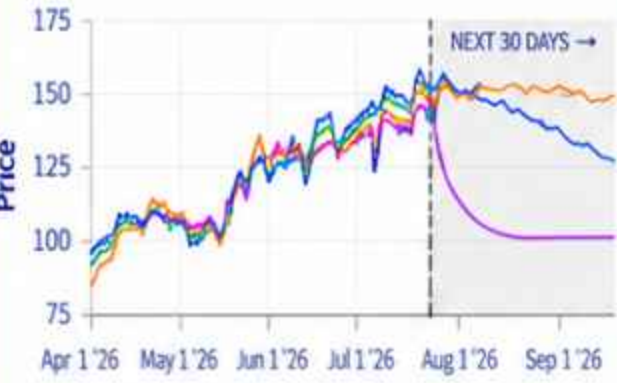
 **PIPU + GPU Prediction**
Prediction generated using the physical PIPU experiment, with GPU-based electronic interface, data handling and control. Nonlinear photonic transformation is performed by the PIPU platform.

 **AI Prediction**
Advanced time-series machine-learning comparator used for short-horizon prediction. Operates during the observed regime.

 **GPU Prediction**
Numerical simulation of the PIPU dynamical model executed entirely on GPU.

 **JPM**

Autonomous Price Prediction (USD)

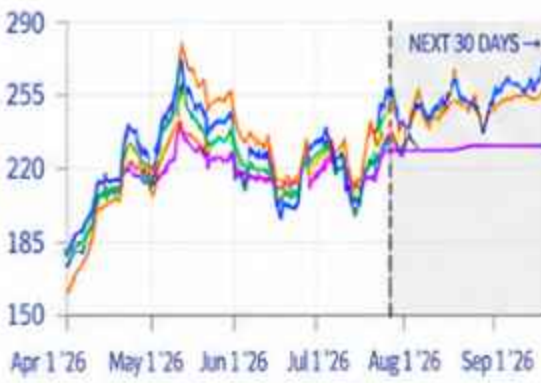


Quantitative Snapshot (Observed Window: Apr 1, 2026 – Aug 31, 2026)

Metric	Actual	PIPU + GPU	AI	GPU
Mean Price	124.5	126.8	135.1	120.8
Std. Deviation	21.8	21.1	21.5	22.6
Observed Range	91.7 – 163.7	91.7 – 176.9	96.6 – 166.5	86.1 – 165.3
Relative Range	25.9%	28.9%	24.5%	25.9%
MAE (vs Actual)	-	3.8	4.2	6.1
RMSE (vs Actual)	-	4.9	5.8	8.7
NRMSE (vs Actual)	-	1.5%	1.8%	2.7%

 **NVDA**

Autonomous Price Prediction (USD)



Quantitative Snapshot (Observed Window: Apr 1, 2026 – Aug 31, 2026)

Metric	Actual	PIPU + GPU	AI	GPU
Mean Price	208.5	201.2	186.7	186.4
Std. Deviation	15.4	15.8	15.6	14.9
Observed Range	181.3 – 256.5	183.3 – 262.1	172.1 – 240.1	185.2 – 263.7
Relative Range	42.5%	37.3%	37.2%	32.8%
MAE (vs Actual)	-	3.9	4.6	6.3
RMSE (vs Actual)	-	5.1	6.2	8.4
NRMSE (vs Actual)	-	2.5%	3.1%	4.2%

 **RELIANCE**

Autonomous Price Prediction (INR)



Quantitative Snapshot (Observed Window: Apr 1, 2026 – Aug 31, 2026)

Metric	Actual	PIPU + GPU	AI	GPU
Mean Price	2536.6	2321.4	2083.9	1883.2
Std. Deviation	62.7	59.8	57.4	61.1
Observed Range	2051 – 2813	1987 – 2803	1985 – 2663	1823 – 2833
Relative Range	36.9%	34.9%	27.8%	26.9%
MAE (vs Actual)	-	13.6	16.8	19.4
RMSE (vs Actual)	-	17.9	22.1	26.7
NRMSE (vs Actual)	-	1.4%	1.7%	2.1%

Results and Observations (2026 Validation, Set 2)

1 Dataset Characteristics

The three datasets exhibit distinct market behaviours in 2026. JPMorgan shows a broadly upward trend with moderate volatility, NVIDIA exhibits higher short-term fluctuations, and Reliance Industries shows larger directional movements with higher absolute price levels in INR.

2 Observed-Window Performance

Across the four datasets (Apr 1, 2026 – Aug 31, 2026), the PIPU + GPU predictions closely follow the actual price dynamics across all three datasets, with lower error metrics compared. Performance is dataset-dependent, with NVIDIA showing higher relative variability.

3 Autonomous Inference (Next 30 Days)

In the autonomous phase, PIPU + GPU maintains a coherent trajectory for all four datasets. For ADNOC and FAB the trajectory remains within a similar operating range. For JPMorgan and NVIDIA, the PIPU + GPU trajectories remain closer to the subsequent actual prices, while GPU-only shows larger deviations. For Reliance, it models broader movement, with PIPU + GPU capturing the downward direction.

4 Key Takeaways

The 2026 results demonstrate that the physical PIPU platform can provide real-world financial market dynamics and maintain a coherent autonomous trajectory across diverse datasets. Performance varies with dataset characteristics, highlighting the importance of broader validation and further evaluation.

FINANCIAL TIME-SERIES INFERENCE

Validation on 2024 Dataset

Observed vs Predicted Performance Across Selected Companies (2024)

The 2024 validation evaluates the PIPU platform using real-world financial market datasets. Results show strong alignment between the PIPU + GPU predictions and actual market dynamics, with company-specific behaviours and the expected divergence of the GPU-only model in the autonomous phase (next 30 days).

 **SUPPORTING DATA**
Open Access on Zenodo

Dataset: "PIPU Autonomous Prediction Training and Inference Datasets for Whitepaper"

All results use the same experimental parameter window (edge-of-chaos configuration) stored as a weight file on our server.

WHY 2024?

The year 2024 was selected as a post-COVID normalisation period. During this time, major financial markets showed meaningful temporal variation as investors adapted to the new normal, and the rapid growth of the AI sector added further dynamics. This provided a realistic test window for nonlinear temporal companies and sectors.

COMPARISON METHODS

- **Actual**
Observed market time-series data used as the reference against which the prediction outputs are compared.
- **PIPU + GPU Prediction**
Prediction generated using the physical PIPU experiment, with GPU-based electronic interface, data handling and control. Nonlinear photonic transformation is performed by the PIPU platform.
- **AI Prediction**
Advanced time-series machine-learning comparator used for short-horizon prediction. Operates in one step-ahead mode without seeing future values.
- **GPU Prediction**
Numerical simulation of the PIPU dynamical model executed entirely on a GPU. Represents a computational baseline to the physical PIPU system.



Quantitative Snapshot (Observed Window)

Metric	Actual	PIPU + GPU	AI	GPU
Mean Price	136.6	136.9	136.0	131.1
Std. Deviation	12.8	13.1	6.7	13.4
Observed Range	116.2 – 160.6	138.4 – 171.1	117.6 – 160.3	111.3 – 163.8
Relative Range	17.9%	14.6%	14.8%	11.9%
MAE (vs Actual)	-	4.2	6.8	11.7
RMSE (vs Actual)	-	5.1	9.5	14.5



Quantitative Snapshot (Observed Window)

Metric	Actual	PIPU + GPU	AI	GPU
Mean Price	145.8	149.5	155.9	166.6
Std. Deviation	7.9	8.1	9.1	13.1
Observed Range	104.9 – 178.3	106.1 – 180.4	145.8 – 180.3	108.3 – 176.9
Relative Range	12.9%	14.7%	11.0%	16.6%
MAE (vs Actual)	-	3.6	7.9	14.0
RMSE (vs Actual)	-	7.1	9.8	16.6



Quantitative Snapshot (Observed Window)

Metric	Actual	PIPU + GPU	AI	GPU
Mean Price	86.1	84.9	82.9	73.2
Std. Deviation	34.7	31.9	36.6	18.4
Observed Range	28.1 – 117.4	30.1 – 119.3	26.7 – 119.3	111.1 – 134.1
Relative Range	62.4%	51.9%	60.0%	16.9%
MAE (vs Actual)	-	6.6	9.8	18.9
RMSE (vs Actual)	-	8.1	13.2	24.7



Quantitative Snapshot (Observed Window)

Metric	Actual	PIPU + GPU	AI	GPU
Mean Price	1355.6	1314.4	1308.9	1303.2
Std. Deviation	62.7	59.8	57.4	61.1
Observed Range	1836.1 – 2813.1	1928.7 – 2692.5	1936.5 – 2483.9	1892.3 – 2812.9
Relative Range	36.5%	34.9%	27.8%	25.5%
MAE (vs Actual)	-	13.6	16.8	19.4
RMSE (vs Actual)	-	17.9	22.1	26.7

Key Results and Observations (2024 Validation)

- 1

Overall Performance
Across all four companies, the PIPU + GPU predictions closely track the actual market data during the observed window, with lower error metrics than the AI and GPU-only models.
- 2

Dataset-Specific Dynamics
PIPU predictions achieve stable behaviour. Amazon exhibits moderate short-term fluctuations, and NVIDIA shows higher volatility. Reliance Industries shows larger directional movements with higher absolute price levels in INR.
- 3

Autonomous Inference (Next 30 Days)
In the autonomous phase, the PIPU + GPU maintains coherent trajectories consistent with recent trends, while the GPU-only model diverges significantly in all cases.
- 4

Implications for Long-Horizon
These results demonstrate that the physical PIPU platform can provide real-world financial market dynamics and maintain a coherent autonomous trajectory across diverse datasets. Performance varies with dataset characteristics, highlighting the importance of broader validation and further evaluation.

FINANCIAL TIME-SERIES INFERENCE

Validation Continued

Observed vs Predicted Performance Across Selected Companies (2024)

The 2024 validation evaluates the PIPU platform using real-world financial market datasets. Results show strong alignment between the PIPU + GPU predictions and actual market dynamics, with company-specific behaviours and the expected divergence of the GPU-only model in the autonomous phase (next 30 days).

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The year 2024 was selected as a post-COVID normalisation period. During this time, major financial markets showed meaningful temporal variation as investors adapted to the new normal, and the rapid growth of the AI sector added further dynamics. This provided a realistic test window for nonlinear temporal companies and sectors.

COMPARISON METHODS

Actual
Observed market time-series data used as the reference against which the prediction outputs are compared.

PIPU + GPU Prediction
Prediction generated using the physical PIPU experiment, with GPU-based electronic interface, data handling and control. Nonlinear photonic transformation is performed by the PIPU platform.

AI Prediction
Advanced time-series machine learning comparator operating during the observed regime, trained to minimise forecast error on market trends without the need for measured photonic execution.

GPU Prediction
Numerical simulation of the PIPU dynamical model executed entirely on GPU, typically showing larger divergence in the autonomous phase due to absence of real hardware inference.



Quantitative Snapshot (Observed Window)

Metric	Actual	PIPU + GPU	AI	GPU
Mean Price	2.20	2.21	2.20	2.18
Std. Deviation	0.086	0.041	0.084	0.061
Observed Range	2.11 – 2.29	2.14 – 2.28	2.13 – 2.27	2.10 – 2.26
Relative Range	8.2%	6.3%	6.6%	7.8%
MAE (vs Actual)	-	0.028	0.036	0.071
RMSE (vs Actual)	-	0.036	0.045	0.085



Quantitative Snapshot (Observed Window)

Metric	Actual	PIPU + GPU	AI	GPU
Mean Price	11.03	11.09	11.01	10.95
Std. Deviation	0.22	0.19	0.21	0.28
Observed Range	10.68 – 11.48	10.75 – 11.33	10.72 – 11.40	10.60 – 11.52
Relative Range	7.2%	5.7%	6.2%	8.4%
MAE (vs Actual)	-	0.17	0.21	0.38
RMSE (vs Actual)	-	0.23	0.29	0.47



Quantitative Snapshot (Observed Window)

Metric	Actual	PIPU + GPU	AI	GPU
Mean Price	125.6	125.1	124.8	123.7
Std. Deviation	3.8	3.1	3.5	5.6
Observed Range	118.2 – 132.9	120.1 – 130.8	119.5 – 130.1	115.1 – 133.4
Relative Range	11.1%	8.5%	8.9%	14.8%
MAE (vs Actual)	-	2.6	3.1	5.7
RMSE (vs Actual)	-	3.4	4.2	7.9

Dataset Overview (Set 2)

Company	Sector	Closing Price (May 30, 2024)	Price Range (2024)	Key Characteristics
ADNOC	Energy	AED 2.1635	2.11 – 2.29	Moderate volatility, upward trend in second half
FAB	Banking	AED 11.1514	10.68 – 11.48	Range-bound with regime shift in Apr 2024
Apple	Technology	\$122.39	118.2 – 132.9	Higher volatility, cyclical behaviour, trend reversal in Q2

Experimental Configuration

Component	Description
PIPU + GPU	Physics-native PIPU inference with GPU data pipeline and pre/post-processing
AI Model	Transformer-based model (same training window)
GPU Model	Numerical simulation using GPU reservoir model
Prediction	Autonomous inference for next 30 days (no additional training)

Key Results and Observations (2024 Validation)

- 1 Dataset Characteristics**
Across all four companies, the PIPU + GPU predictions closely track the actual market data during the observed window, with lower error metrics than the AI and GPU-only models.
- 2 Model Performance**
PIPU predictions achieve stable behaviour. Amazon exhibits moderate short-term fluctuations, and NVIDIA shows higher volatility. Reliance Industries shows larger directional movements with higher absolute price levels in INR.
- 3 Autonomous Inference (Next 30 Days)**
In the autonomous phase, the PIPU + GPU maintains coherent trajectories consistent with recent trends, while the GPU-only model diverges significantly in all cases.
- 4 Implications for Autonomous Inference**
These results demonstrate that the physical PIPU platform can provide real-world financial market dynamics and maintain a coherent autonomous trajectory across diverse dataset characteristics, highlighting of broader validation and further evaluation.

SERVICE MODEL

PIPU as a Managed Photonic Compute Service

Secure Data-to-Inference Workflow for Real-World Applications

PIPU is structured as a managed compute service in which users interact through a secure cloud layer while the physical photonic platform performs the core experimental training and inference workflow.



SUBSEQUENT INFERENCE

Stored dataset configurations enable efficient inference without repeating the full training workflow.



FROM PLATFORM TO SERVICE



THE PATH AHEAD

From Experimental Validation to External Access

Preparing PIPU for the Next Stage of Deployment

The results presented in this whitepaper mark an important transition for PIPU: from demonstrating experimental capability toward establishing the technical, operational and governance foundations required for controlled external access.

The next phase is therefore not simply another experiment. It is the progressive translation of PIPU into an accessible photonic compute capability.

PIPU DEPLOYMENT PATHWAY



WHAT EXTERNAL ACCESS ENABLES



FOR RESEARCHERS

Evaluate physics-native photonic computing on new datasets and computational problems.



FOR INDUSTRY

Explore PIPU against application-specific workloads through a managed interface.



FOR THE PLATFORM

Generate broader evidence, user feedback and application insight to guide future development.

ACCESS THE PIPU SERVICE



Researchers, industry organisations and technology partners can access the PIPU service through our official platform at:

www.quantlase.com

The PIPU service provides a secure interface to explore datasets, submit inference requests and access results, subject to governance and approval arrangements.

FROM EVIDENCE TO IMPACT



The objective is clear: preserve the scientific integrity of PIPU while progressively making its capabilities accessible for meaningful real-world evaluation.



Full public deployment of the PIPU service will follow the finalisation of technical readiness, governance requirements and formal declaration by H/C.

OUR TEAM

The Scientific Team Behind PIPU

Complementary Expertise from Research to Real-World Impact

Our team brings together deep research, data science, engineering and product expertise to advance PIPU from fundamental photonic concepts to validated real-world applications.

From fundamental photonic dynamics to real-world applications, our team combines research, data analysis, technical execution and productisation to advance PIPU.





Dr. Pramod Kumar, Ph.D.
(Laser Tech)
Director of Research, QRDC

- Conceived and architected the PIPU concept and underlying photonic intelligence framework.
- Leads fundamental research in nonlinear photonic dynamics and edge-of-chaos computing.
- Provides strategic scientific direction and long-term vision for PIPU and its applications.



Vision & Research Architecture





Dr. Salman Abdullah
Product Director, QRDC

- Industry Product Role – Data Analysis**
- Led the complete data analysis across all datasets reported in this whitepaper, including the experimental results and the statistical analysis presented in the Appendix.
 - Designed the evaluation methodology, performed cross-dataset analysis, derived quantitative metrics and generated all comparative plots and statistical summaries.
 - Translates research results into a clear and practical product strategy, market positioning and ecosystem engagement.
 - Bridges technology, industry and real-world use cases, enabling the path to a managed PIPU compute service.



Data Analysis, Product Strategy & Global Impact





Mr. Deepanshu Baisoya
Lead PIPU Engineer, QRDC

- Leads hardware implementation, system integration and experimental realisation of PIPU.
- Develops and validates optical computing architectures, control systems and measurement pipelines.
- Conducts comprehensive testing, system characterisation and performance evaluation.
- Drives continuous development of the experimental platform and data acquisition workflows.

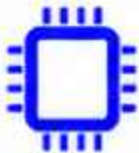


Engineering & Experimental Realisation

A SHARED MISSION

We combine deep scientific research, data analysis, advanced engineering and real-world application development to make physics-native photonic computing a practical and accessible capability for global markets.

*From lab research
to real-world impact.*



Scientific
Innovation



Technical
Excellence



Real-World
Applications



Global
Collaboration

APPENDIX

Cross-Dataset Statistical Analysis

Comparative Quantitative Summary of PIPU Experimental Validation Across 2024 and 2026 Datasets

Consolidated statistical analysis of the validation datasets reported in this whitepaper, enabling comparison of dataset characteristics and model performance across experimental periods.

● 2024 Validation | ● 2026 Validation

1. Actual Mean Price (descriptive only)

Dataset mean closing price (no performance implication across companies due to different price scales).



2. Actual Standard Deviation

Observed price standard deviation (dataset characteristic).



3. Actual Relative Range

Scale-independent measure of dataset price range.

$$\text{Relative Range (\%)} = \frac{(\text{High} - \text{Low})}{\text{Mean}} \times 100$$



4. PIPU + GPU Mean-Price Error

Absolute percentage difference between PIPU + GPU mean and Actual mean.

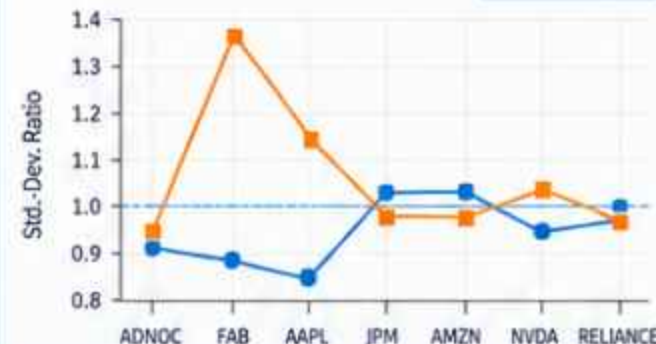
$$\text{Mean-Price Error (\%)} = \frac{|\mu_{\text{PIPU+GPU}} - \mu_{\text{Actual}}|}{\mu_{\text{Actual}}} \times 100$$



5. PIPU + GPU Std.-Dev. Ratio

Ratio of PIPU + GPU standard deviation to Actual standard deviation.

$$\text{Std.-Dev. Ratio} = \frac{\sigma_{\text{PIPU+GPU}}}{\sigma_{\text{Actual}}}$$



6. PIPU + GPU Relative-Range Error

Absolute difference in relative range between PIPU + GPU and Actual.

$$\text{Relative-Range Error (percentage points)} = |\text{RR}_{\text{PIPU+GPU}} - \text{RR}_{\text{Actual}}|$$



7. PIPU + GPU RMSE

Root mean square error versus Actual.

$$\text{RMSE} = \sqrt{\frac{1}{n} \sum_{i=1}^n (\hat{y}_i - y_i)^2}$$



8. PIPU + GPU NRMSE

Normalized RMSE as a percentage of Actual mean.

$$\text{NRMSE (\%)} = \frac{\text{RMSE}}{\mu_{\text{Actual}}} \times 100$$



9. RMSE by Model (2026)

Comparison of RMSE for PIPU + GPU, AI and GPU models (2026 validation).



KEY ANALYTICAL TAKEAWAYS

- Dataset scale and volatility differ materially across companies; relative range is the more appropriate cross-company descriptor than raw price or raw RMSE.
- Across the 14 reported company-year windows, the median PIPU + GPU mean-price error is 0.5%, while the median standard-deviation ratio is 0.96, indicating close agreement with observed dispersion.
- For 2026, reported PIPU + GPU NRMSE spans 1.2% to 3.9%. Across all reported windows, median RMSE reduction versus AI is 21% and versus GPU-only is 57%.
- The absolute relative-range mismatch has a median of 2.0 percentage points. The combined results support broader quantitative validation rather than a single universal performance claim.

DERIVED METRIC FORMULAS

Mean-Price Error (%)

$$100 \times \frac{|\mu_{\text{PIPU+GPU}} - \mu_{\text{Actual}}|}{\mu_{\text{Actual}}}$$

Std.-Dev. Ratio

$$\frac{\sigma_{\text{PIPU+GPU}}}{\sigma_{\text{Actual}}}$$

Relative-Range Error (percentage points)

$$|\text{RR}_{\text{PIPU+GPU}} - \text{RR}_{\text{Actual}}|$$

RMSE

$$\sqrt{\frac{1}{n} \sum_{i=1}^n (\hat{y}_i - y_i)^2}$$

NRMSE (%)

$$100 \times \frac{\text{RMSE}}{\mu_{\text{Actual}}}$$

Relative Range (%)

$$\frac{(\text{High} - \text{Low})}{\text{Mean}} \times 100$$

METHODOLOGICAL NOTE



For the 2024 validation datasets, non-trading dates were forward/backward filled to maintain a continuous time-series input. This preprocessing can shift the correspondence between displayed market-date values and historical closing prices and is not treated here as prediction error.

ADDITIONAL NOTES

- Only metrics explicitly reported in the whitepaper have been used.
- Missing values remain unreported and are not estimated.
- Different companies operate on different price scales and currencies; normalized metrics are preferred for cross-company comparison.