

Dissemination and valorisation of RFCS-results in the field of “Advanced Automation and Control Solutions in Downstream Steel Processes” and development of a strategic vision for future research

CONTROL^{IN}STEEL



Applications for the steel sector

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Quantum Computing in control applications for the steel sector

Outline

- *Quantum advantages (sensing & communication)*
- Quantum computing.
- Impact on Control applications
- Conclusions



Courtesy from National Academic Press

Project No.: 899208

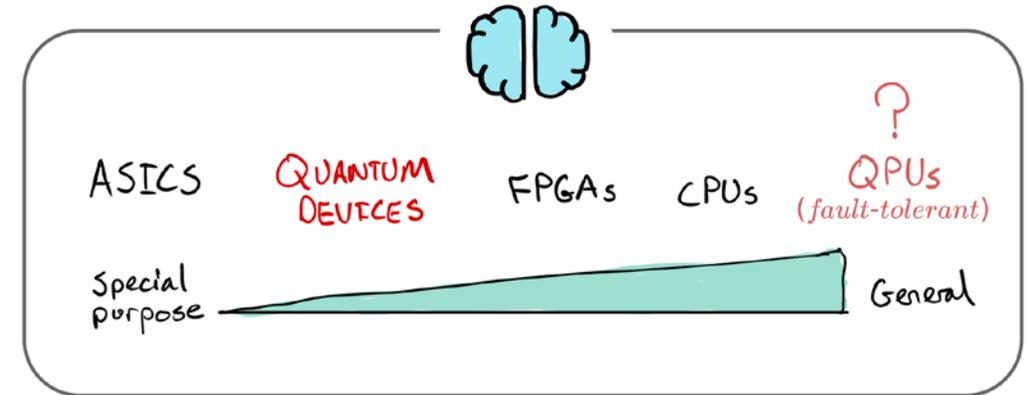
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Quantum Computing in control applications for the steel sector

Quantum advantages

Several edges are becoming relevant:

Quantum sensing, Quantum communication devices, and Quantum computing.



- **Quantum Sensors (QS)** have applications in many fields including positioning systems, communication technology, electric and magnetic field sensors.
- Entanglement in QS can help to create more sensitive magnetometers, able to detect irregularities (defects) in materials.
- Able to model complex systems by positioning photons at specific places.

Quantum Computing in control applications for the steel sector

Quantum advantages

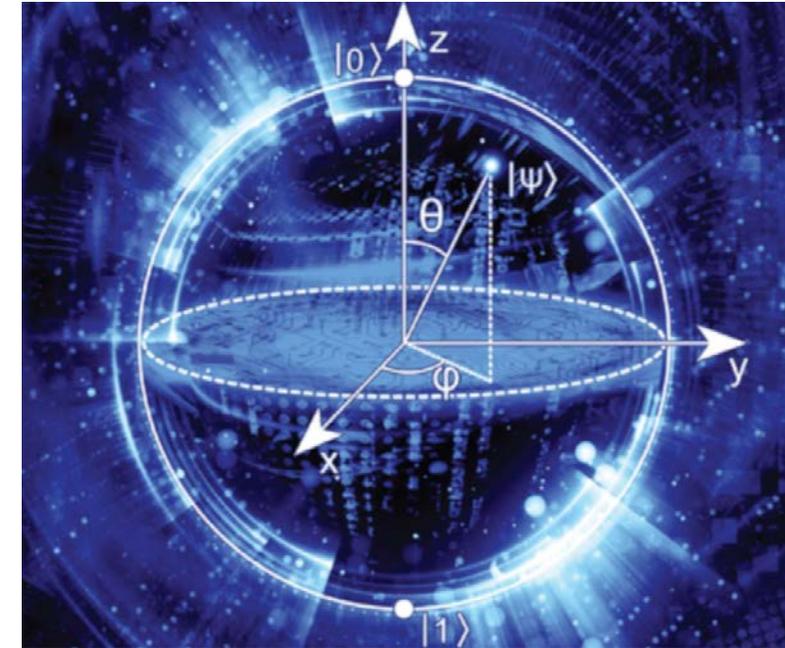
- **Quantum communication devices**, enable quantum entanglement “when two particles are inextricably linked together no matter their separation from one another”. This was suggested to be *faster than the speed of light*, although no changes in the status of particles are allowed.
- Quantum communication takes advantage of the laws of quantum physics to protect data. These laws allow particles—typically photons of light for transmitting data along optical cables—to take on a state of superposition, then no observation can be possible without collapsing its status. It is cybersecure by nature.

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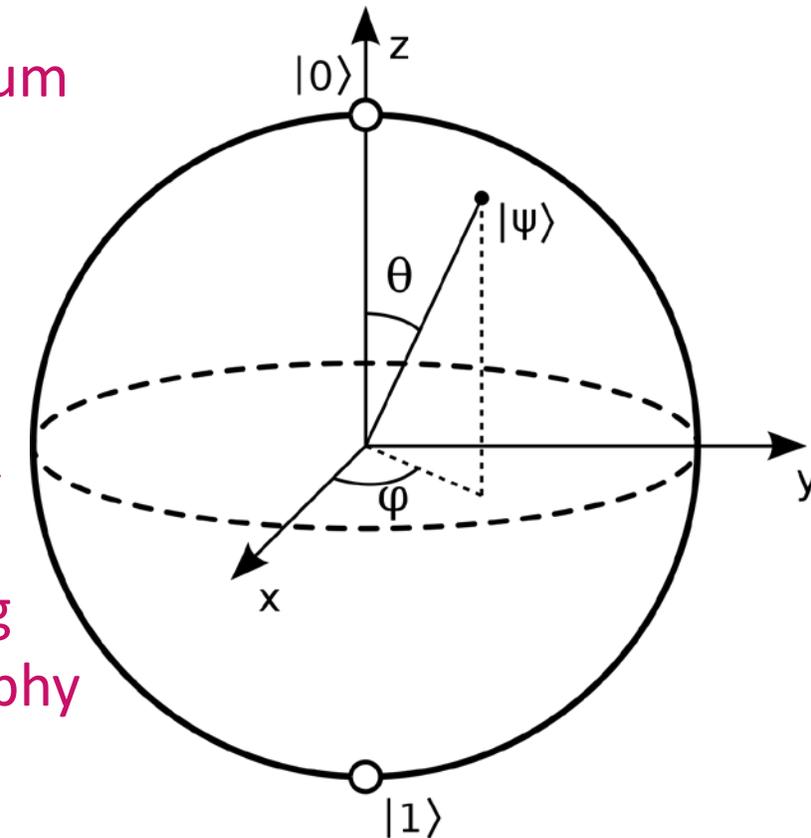
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Quantum computing

- **The quantum computer:** Information processing with quantum computers relies on substantially different laws of physics known as quantum theory: **qubits**.
- Different technologies are available to create qubits, such as **Optical qubits** using light and working at environmental temperature or **Superconducting qubits** working close to 0 K and microwave frequencies.
- Three big areas of development: Quantum Machine Learning (QML), Quantum optimization (QO) and Quantum cryptography (QC)



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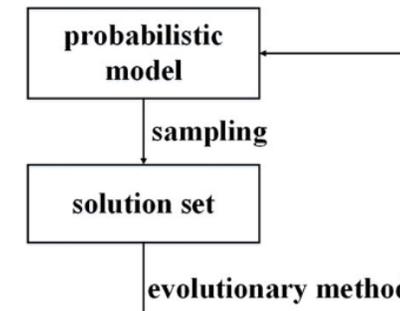
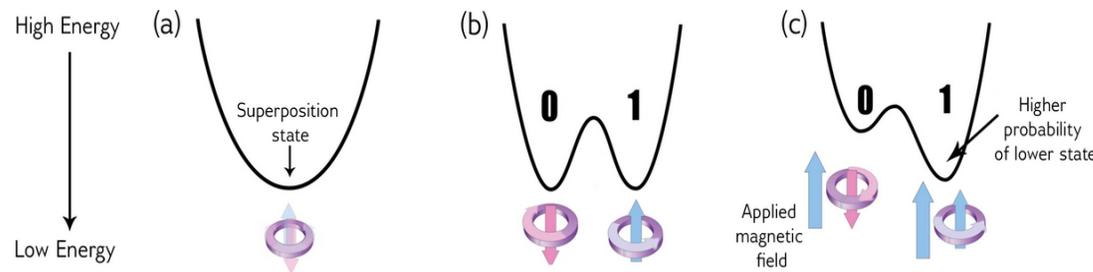
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Quantum computing (optimization)

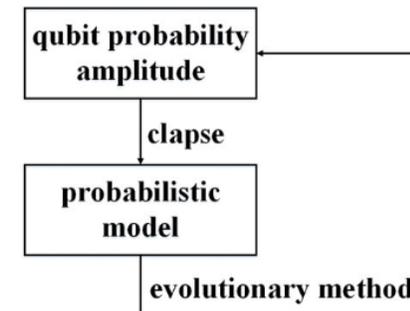
Courtesy: DOI 10.1109/ACCESS.2020.2970105

- Using the unique characteristics of quantum computing, intelligent optimization algorithms can be improved to quantum intelligent optimization methods (QPSO, etc).
- Quantum annealing optimization was enabled by D-wave and helps to solve TSP and other quadratic optimization problems (QBO).

Genetic Algorithm	Quantum System
The evolution population formed by a number of individual	The statistical system formed by a number of quantum
The average population fitness	Energy
Competitiveness between selection pressure and diversity of population	Competitiveness between energy and entropy
Population convergence	Free energy reduces
Get solutions	Non-equilibrium state to equilibrium state



(a) EDA



(b) QEA

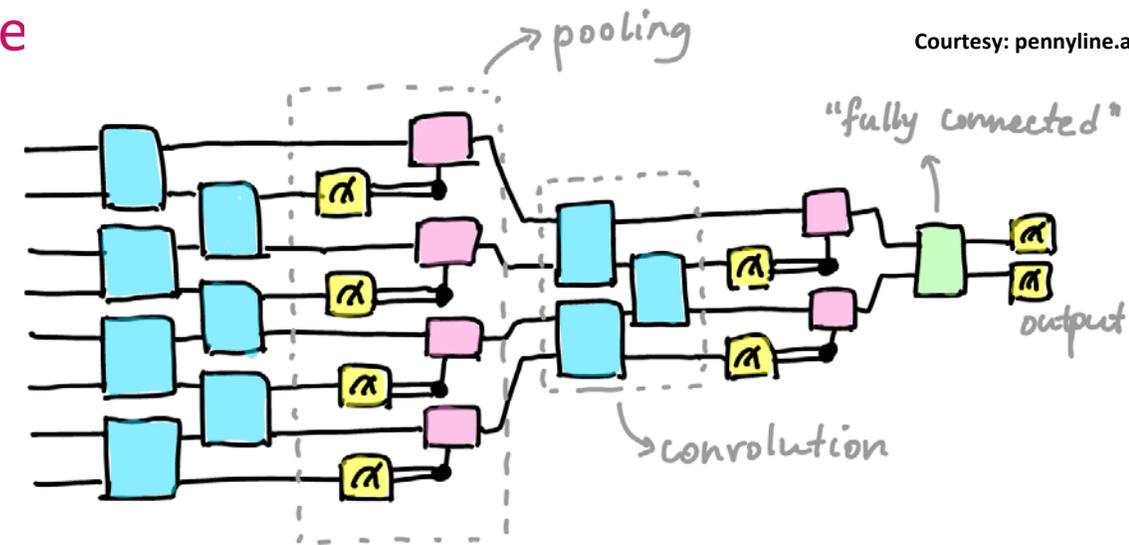
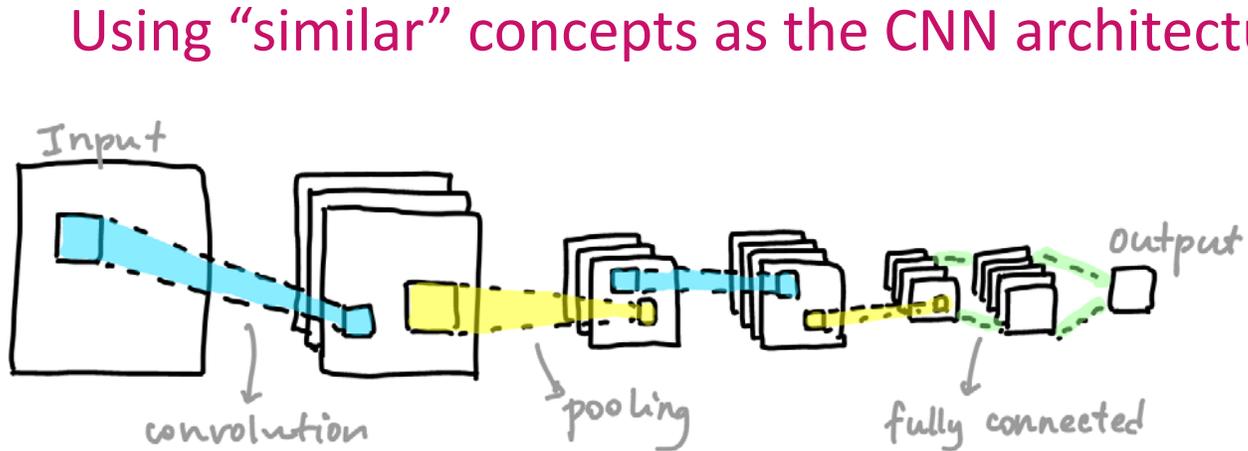
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Quantum Computing in control applications for the steel sector

Quantum computing (ML)

- Using “similar” concepts as the CNN architecture



Courtesy: pennyline.ai

- A set of N qubits can encode information for $2^N - 1$ different states (variables).
- Of course, there are limitations such as **error propagation** and lack of enhanced algorithms **over large sets of qubits**. More development is needed.

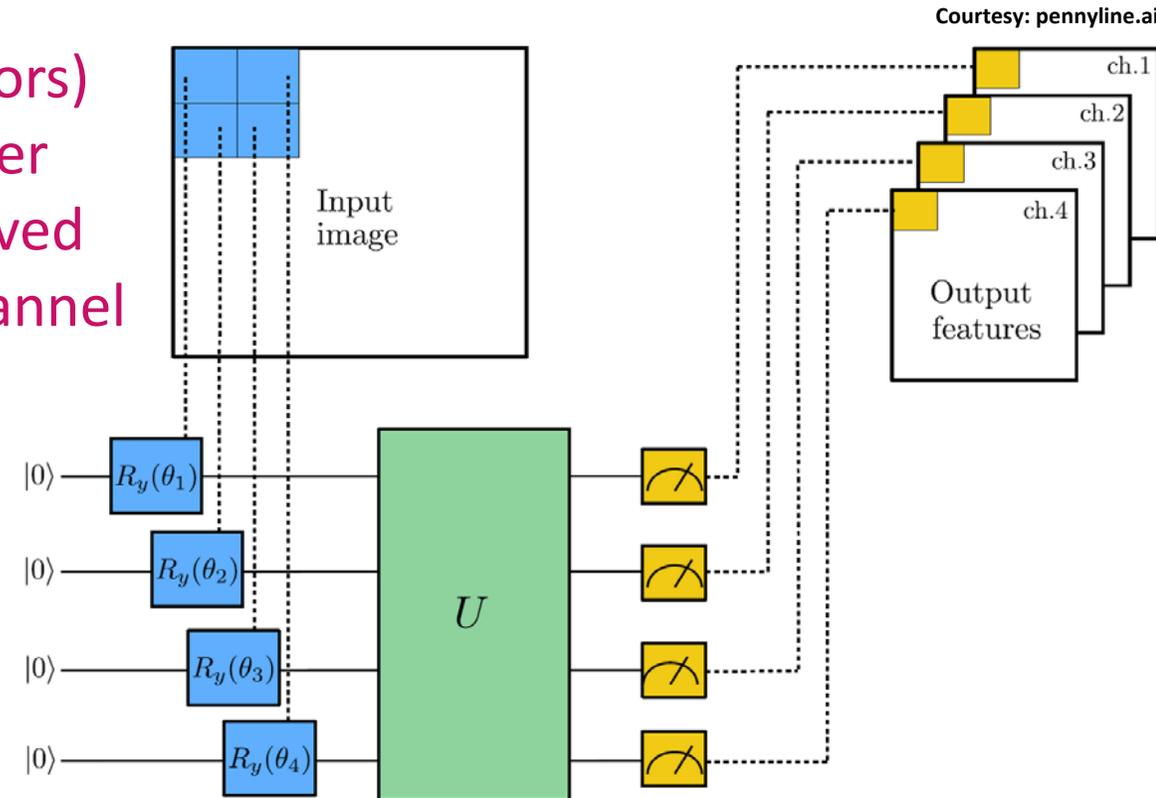
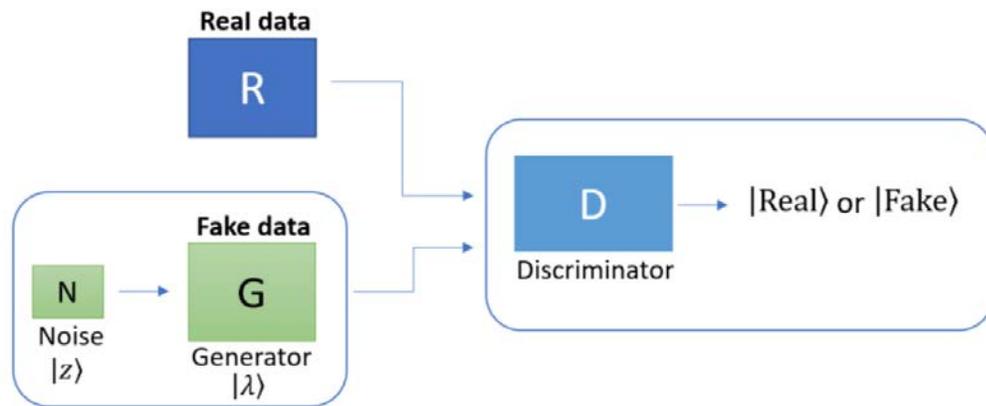
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Quantum Computing in control applications for the steel sector

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Quantum computing (ML)

- Quantvariational operations over images (tensors) can be performed (each pixel plays as parameter for the gate where the transformation U observed will collapse in the different features as per channel
- QGANs are also possible and powerful:



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Quantum Computing in control applications for the steel sector Impact on Control Applications

- **Nippon Steel** and Cambridge Quantum Computing concluded that QC is a powerful tool for companies seeking a competitive advantage, when complex scheduling problems are being undertaken, based on the pilot project they have conducted (<https://www.quantinuum.com/case-study/nippon-steel>). Scheduling is linked to Decision making processes and therefore related to process control.



How Quantum Computing Can Help Nippon Steel Improve Scheduling at Plants

Courtesy:
<https://www.honeywell.com/us/en/news/2021/06/how-quantum-computing-can-help-nippon-steel-improve-scheduling-at-plants>

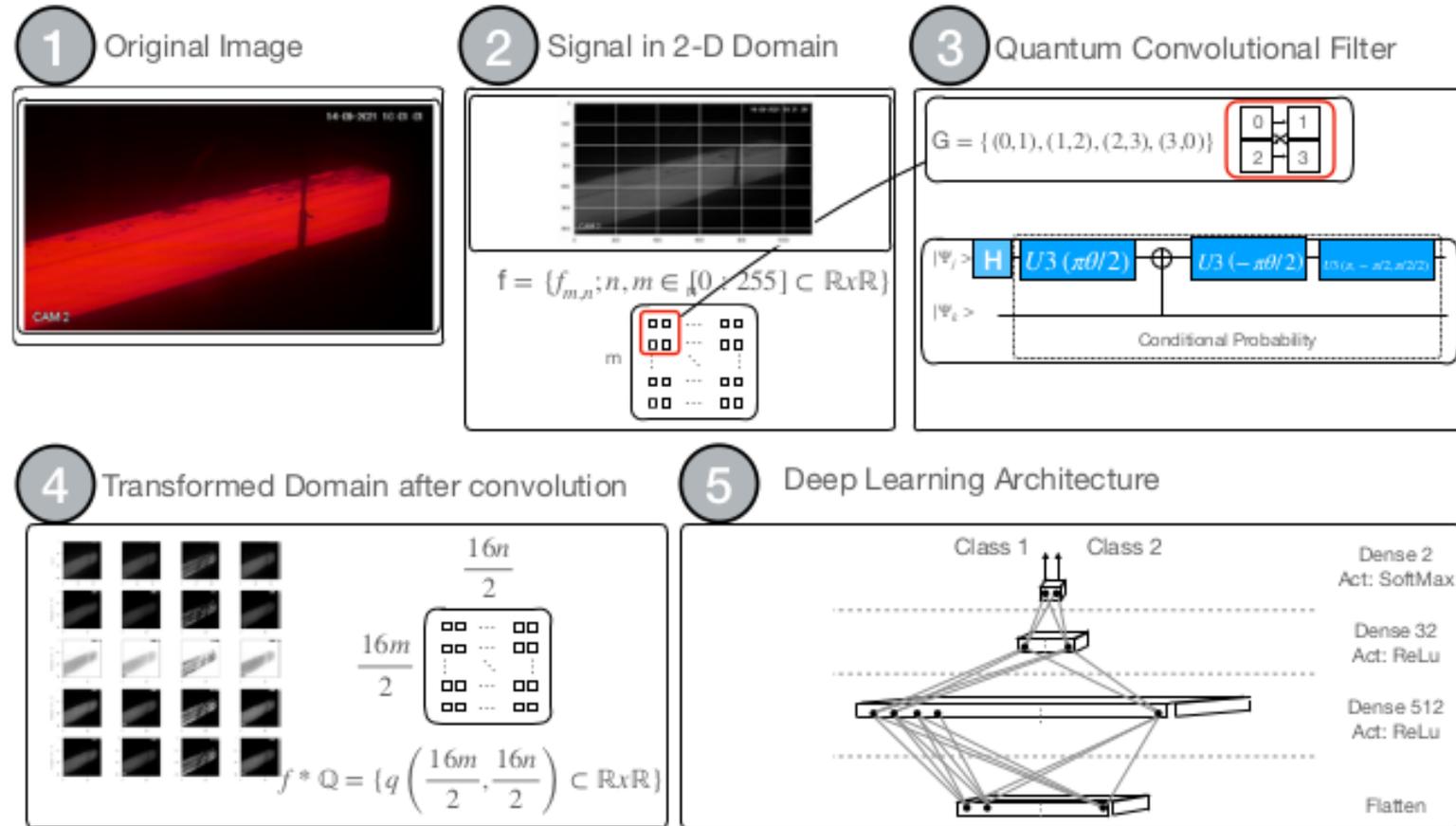
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Impact on Control Applications

An application has been created with Quantum convolutional filters, to preprocess quality images inside furnaces, deciding if scale can be a problem related to the final product. It was shown that the Qclassifier compites with the alternative CNN



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Courtesy: <https://doi.org/10.1016/j.ifacol.2022.04.216>

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Conclusions

- Enormous opportunities for the industry & society are expected from the Quantum technology (devices, ML, communications, etc.)
- Although QT is just at its early stage, it has proved to be useful and competitive in comparison with existing solutions.
- QC enables uncertainty from its design.
- More algorithms will be created, expanding the potential set of applications.
- Intergation between Quantum devices and Quantum computing will be disruptive in industrial applications.

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Thank you for attending this presentation

Merci d'avoir participé à cette présentation

Vielen Dank für Ihre Teilnahme an dieser Präsentation

Gracias por asistir a esta presentación

Grazie per aver partecipato a questa presentazione

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