ENGINEERING HONORS PROGRAM
UNIVERSITY OF MICHIGAN

Convert Batch Reactor to Flow Reactor for Light-Driven CO_2 Reduction and Ammonia Synthesis

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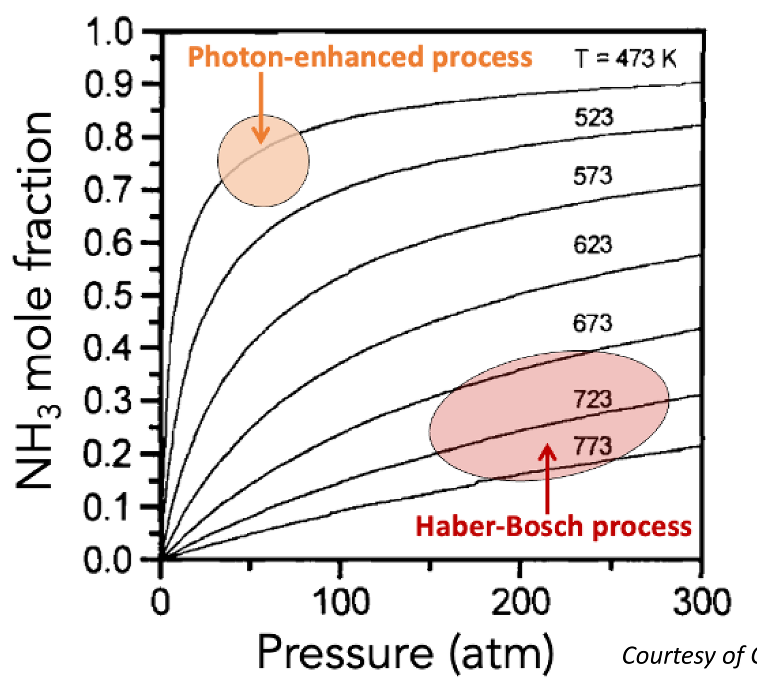
DASGROUPTA INTERFACIAL DESIGN LAB

Introduction

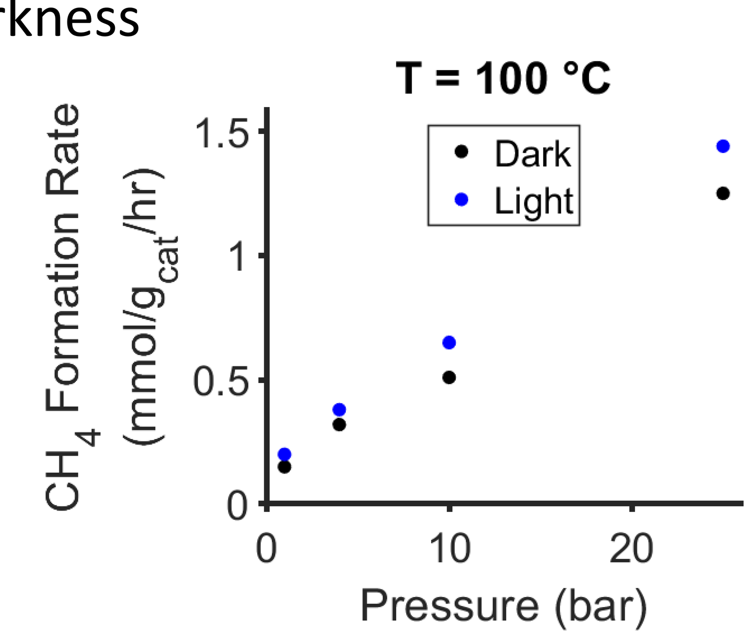
- Fertilizer is used world-wide in agriculture and is a necessity to meet growing food supply needs
  - A key ingredient in fertilizer is ammonia
    - Traditionally made using the Haber-Bosch process, but alternatives are being studied
  - Flow reactors are more industrially relevant than batch reactors.to use in these chemical processes

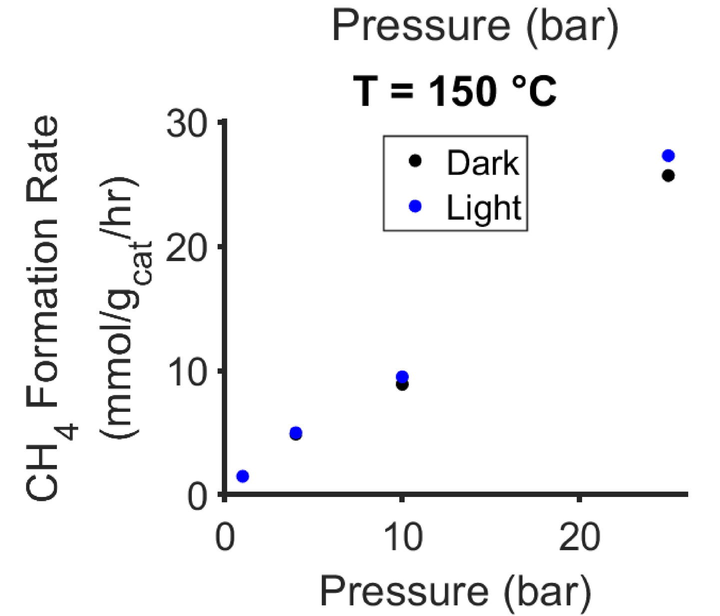


Courtesy of Carissa Yim

Background

- Important energy-intensive hydrogenation reactions:
  - Sabatier Reaction
    - $CO_2 + 4H_2 \xrightarrow[pressure+catalyst]{400°C} CH_4 + 2H_20$
  - Haber-Bosch Process
    - $N_2 + 3H_2 \rightarrow 2NH_3$
- Testing yield for different pressure and temperature combinations in the light and darkness





Current Batch Reactor System

Limitations:

- Manual process
- Large downtime between reaction stages
- Large dead volume of gas within reactor

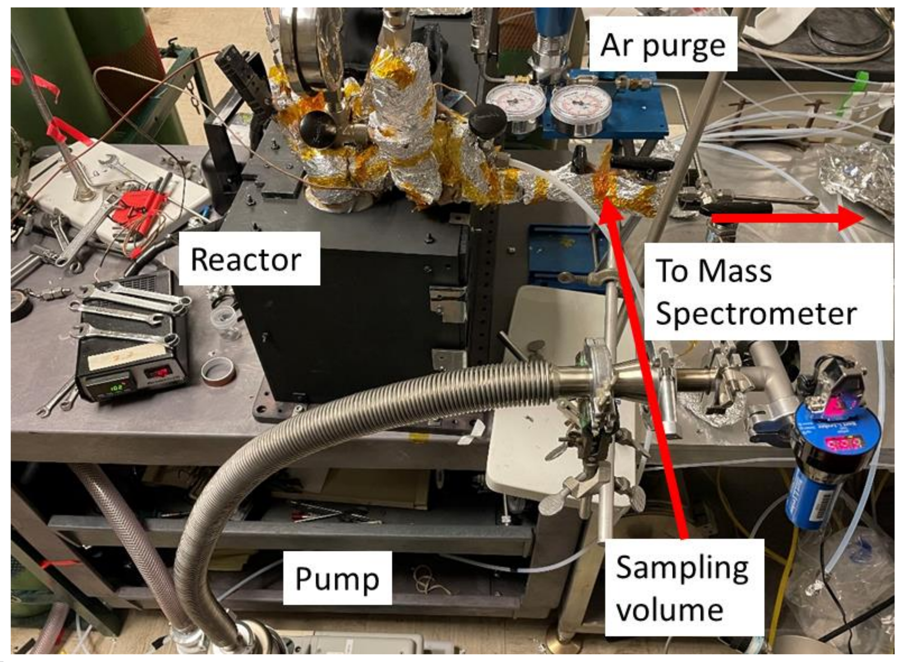
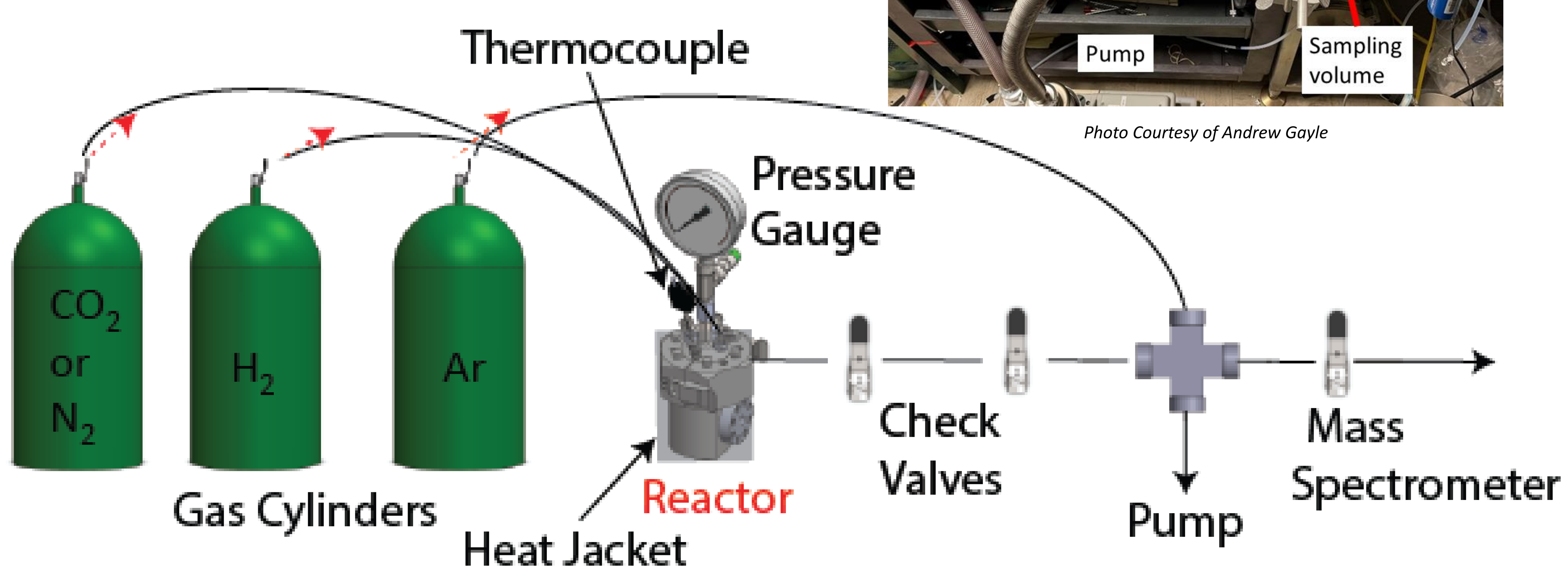
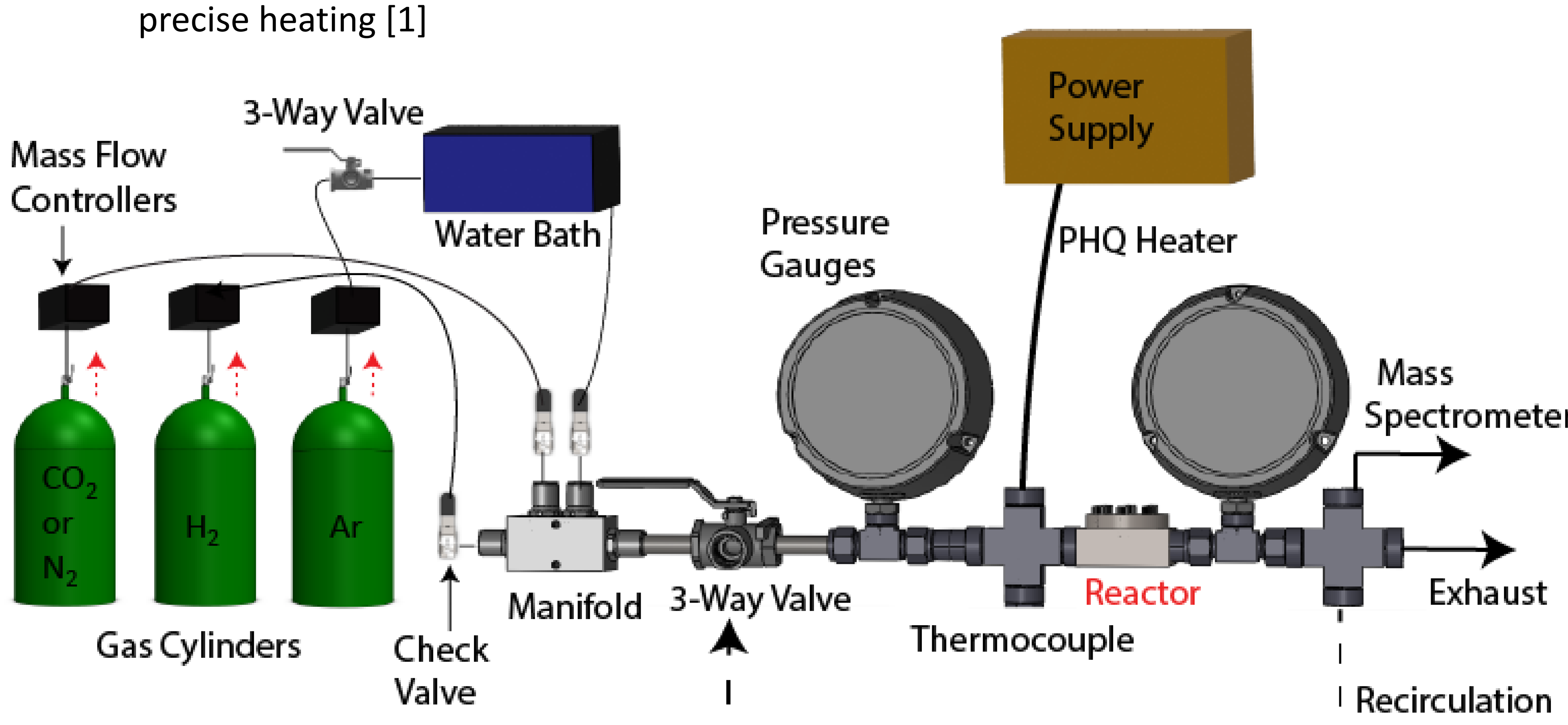


Photo Courtesy of Andrew Gayle

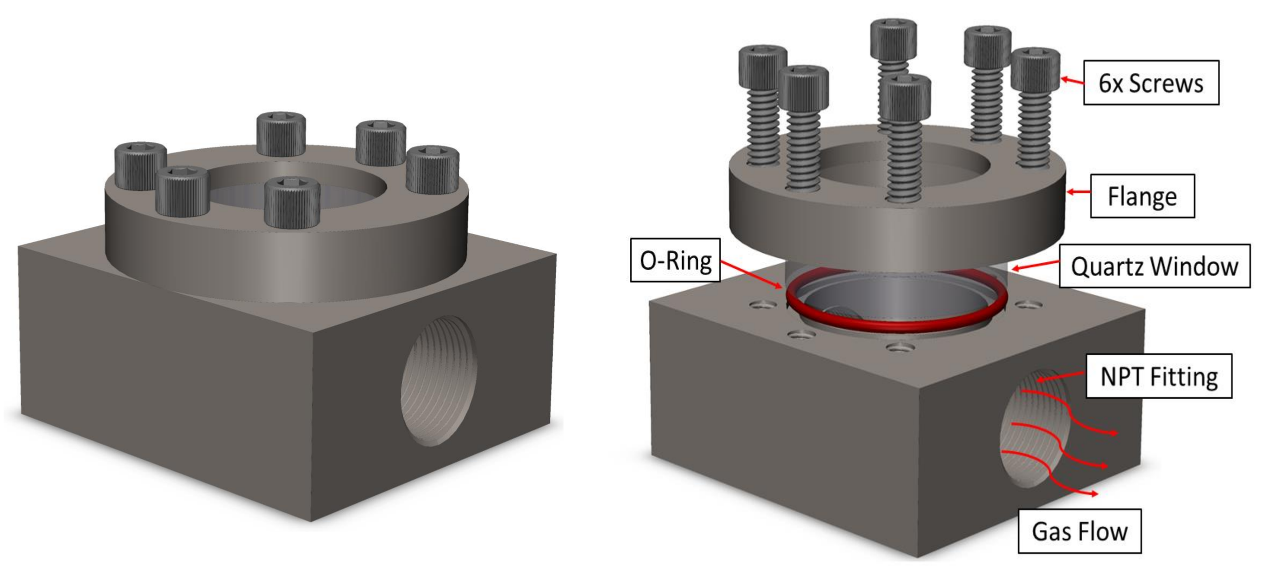


Flow System Design

- Continuous introduction of reactants and collection of gas conversion data
- Allows for more rapid data collection and analysis
- Enables screening of reaction conditions and catalyst architectures
- More freedom for catalyst choice
- Catalyst heating via Programmable Heating and Quenching (PHQ) that allows quick, precise heating [1]



Reactor Design



Conclusion

- A continuous flow reactor will allow greater throughput and more rapid data collection
- The new reactor design will reduce the dead volume by at least 82%
- This new design will also allow light transmissions from 200 nm through the near IR spectrum.
- Future iterations of the reactor will allow for in-situ Fourier-Transform Infrared Spectroscopy
- This project will open the path to design low-emission photoreactors suitable for industrial use.

Acknowledgments

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References

[1] Dong, Q., Yao, Y., Cheng, S. *et al.* Programmable heating and quenching for efficient thermochemical synthesis. *Nature* **605**, 470–476 (2022). https://doi.org/10.1038/s41586-022-04568-6