Fuel Cell Research at the University of South Carolina

John W. Van Zee

University of South Carolina

Columbia, SC

Project ID # FCP8

Overview

Timeline

- Start - Feb 2007
- Finish – Oct 2008
- Percent complete - 5%

Budget

- Total project funding -$2,068,750
  - DOE - $1,655,000
  - Contractor - $ 413,750
- Funding received in FY06 - $0
- Funding for FY07 - $886,607

Barriers

- Barriers addressed
  - A - Durability
  - B - Cost
  - C- Performance

Partners

- Interactions/ collaborations
  - 14 Companies of NSF I/UCRC Center for Fuel Cells
- DOE H2 Quality Team
- Plug Power

OBJECTIVES

Project 1- Non Carbon Supported Catalysts

- Develop novel materials (e.g., Nb doped) for
  - improved corrosion resistance
  - improved fuel cell components

Project 2 -Hydrogen Quality

- Develop a fundamental understanding of
  - performance loss induced by fuel contaminants
  - durability loss fuel induced by contaminants

Project 3 -Gaskets for PEMFCs

- Develop a fundamental understanding of
  - the degradation mechanisms of existing gaskets
  - the performance of improved materials

Project 4 -Acid Loss in PBI-type High Temperature Membranes

- Develop a fundamental understanding of
  - acid loss and acid transport mechanisms
- Predict performance and lifetime as a function of load cycle

Approach: Project 1: Non Carbon Supported Catalysts

Task 1. Development of Titania-based Non-carbon Supports

- **Subtask 1.1 Synthesis of high surface area Nb doped TiO_2**
- **Subtask 1.2 Synthesis of high surface area Ti_4O_7 supports**
- **Subtask 1.3 Deposit catalysts – Form electrodes**

Task 2. Characterization of the Developed Supports & Catalysts

- **Surface and Spectroscopy Methods:**
  (BET, Porosimetry, SEM, TEM, XRD, TGA, XPS, XAS)

Task 3. Electrochemical Characterization

Task 4. Corrosion Studies on Developed Supports & Catalysts

Task 5. Stability Analysis of the Loaded Catalysts with ADT

(ADT = accelerated durability test)

Task 6. Industrial Interaction and Presentations

Approach: Project 2: Hydrogen Quality

Task 1. Group Contaminants by Probable Mechanism
(Adsorption/Desorption, Reactive, Transport Through MEA)

Task 2. Study Effect of Temperature Distributions (75%)
- **Subtask 1.1 Predict temperatures in common cells**
- **Subtask 1.2 Design new laboratory cells**
- **Subtask 1.3 Measure temperature distributions**

Task 3. Design & Perform Experiments by Mechanism
- **Sub Task 3.1 Determine independent adsorption isotherms and rate constants (for CO, a marker compound, as agreed by H2 quality team)**
- **Sub Task 3.2 Extend the methodology to other species**

Task 4. Predict Long-term Effects
Task 5. Exploratory Study with ORNL: Intra-PEMFC Sensors
Task 6. Interact with H2 Quality Team
Task 7. Presentations of Results

Approach: Project 3- Gaskets for PEMFCs

Task 1. Selection of Commercially Available Seal Materials. (95 % complete)

Task 2. Aging of Seal Materials

- **In simulated and accelerated FC environment**
- **With and without stress/deformation**

Task 3. Characterization of Chemical Stability

- **Perform both constant stress & constant displacement tests**
- **Assess the effect of applied stress/deformation on the rate of degradation**
- **Measure chemical/thermal stability will be assessed by various**

Task 4. Characterization of Mechanical Stability

Task 5. Development of Accelerated Life Testing Procedures

Task 6. Industrial Interaction and Presentations

Approach: Project 4-Acid Loss in PBI-type High Temperature Membranes

Task 1. Exercise Existing Computer Code

- **(a) over a range of operating conditions**
- **(b) to determine model limitations**
- **(c) to compare predictions/behavior with existing data.**
- **(d) propose experiments required to improve the model**

Task 2. Additional Experiments and Model Modification

- **Subtask 2.1 - transient experiments**
- **Subtask 2.2 - experiments to understand anode phenomena**
- **Subtask 2.3 - experiments designed from model predictions**

Task 3. Presentations and Publication

Technical Accomplishments/Progress/Results

Project 1: Supports synthesized – characterization in progress

Project 2: Distributions predicted for lab. cell designs

- **See below**
- **Design proposed to minimize temperature gradients**

Project 3: Materials selected & companies engaged

Project 4: Experiments designed with Plug Power

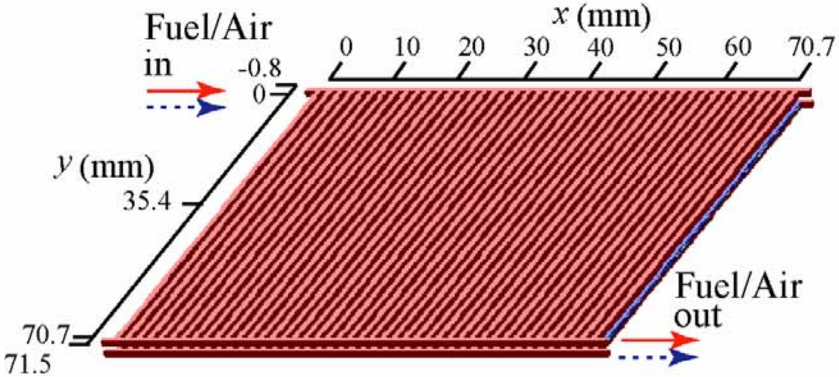
- **Start during June 2007**

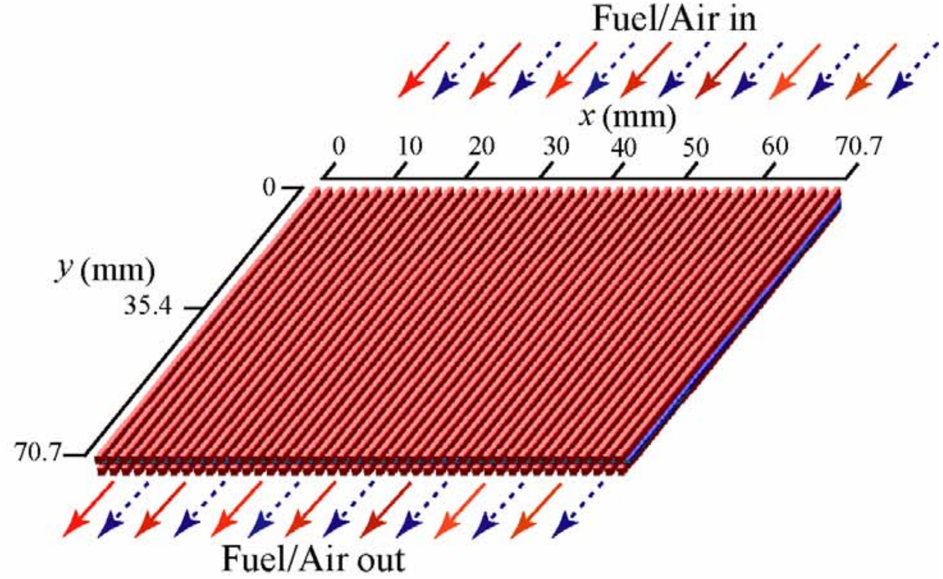
Results: Project 2: Hydrogen Quality- Task 2

Geometry of 50cm^2 straight parallel PEMFC

Conventional cell

Ideal cell



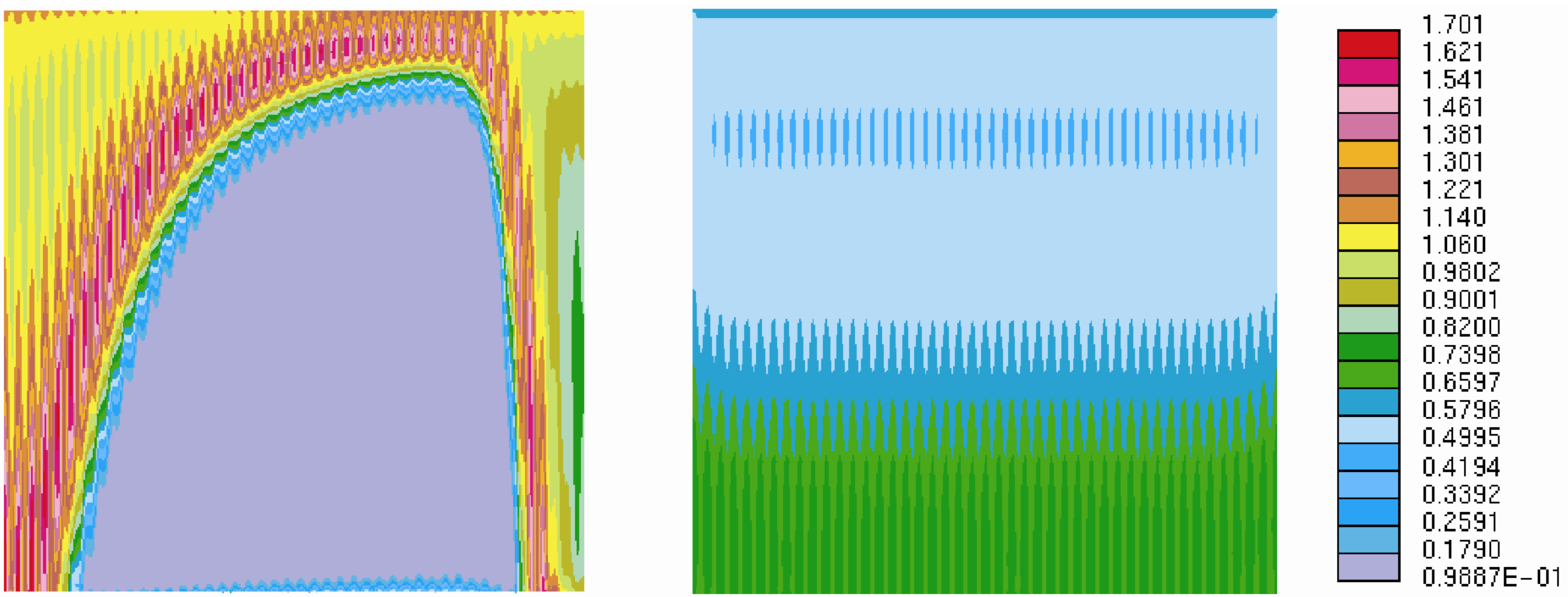


Current density distributions of 50cm^2 straight parallel PEMFCs

(Automotive conditions at 0.6 A/cm^2)

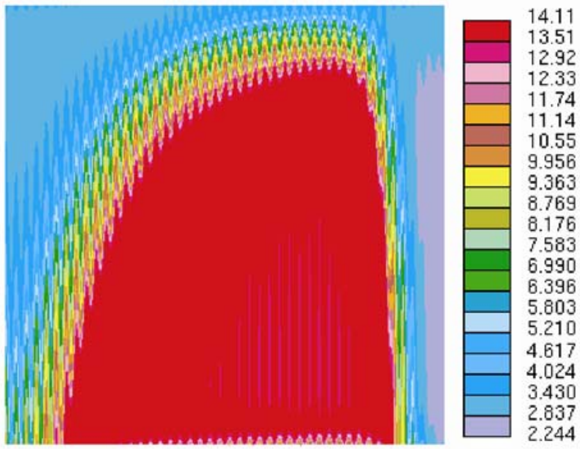
Conventional cell

Ideal cell

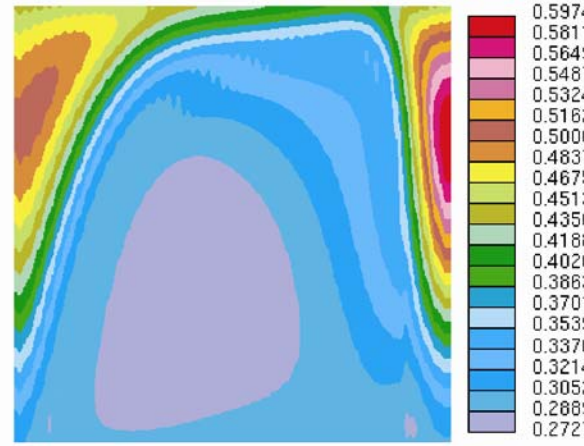


Conventional cell

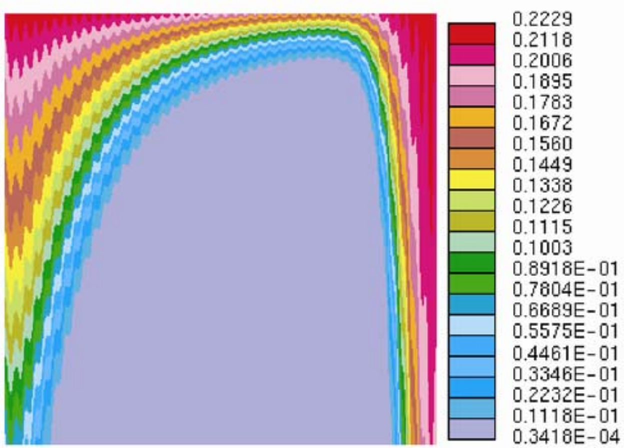
Membrane water contents distribution



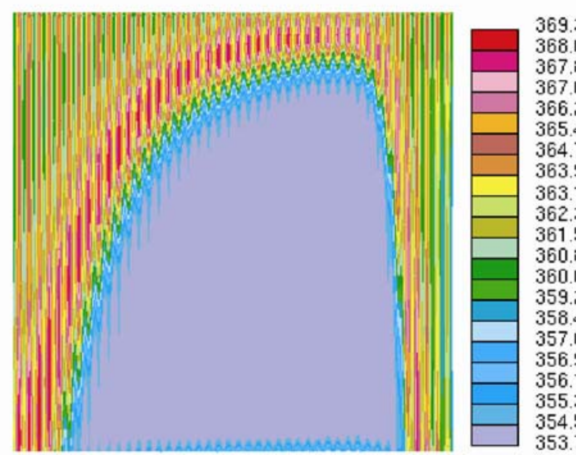
Hydrogen mole fraction distribution



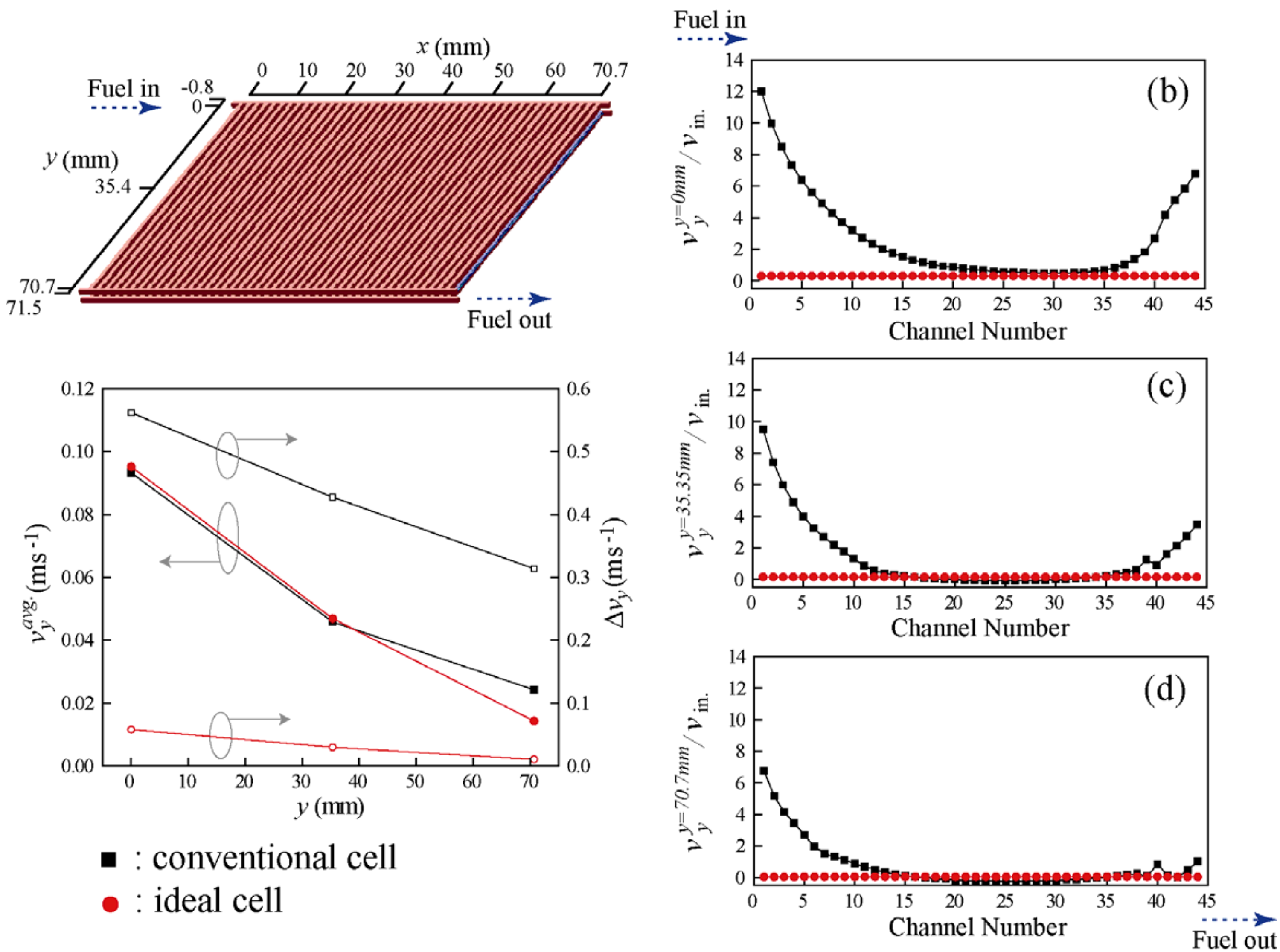
Oxygen mole fraction distribution



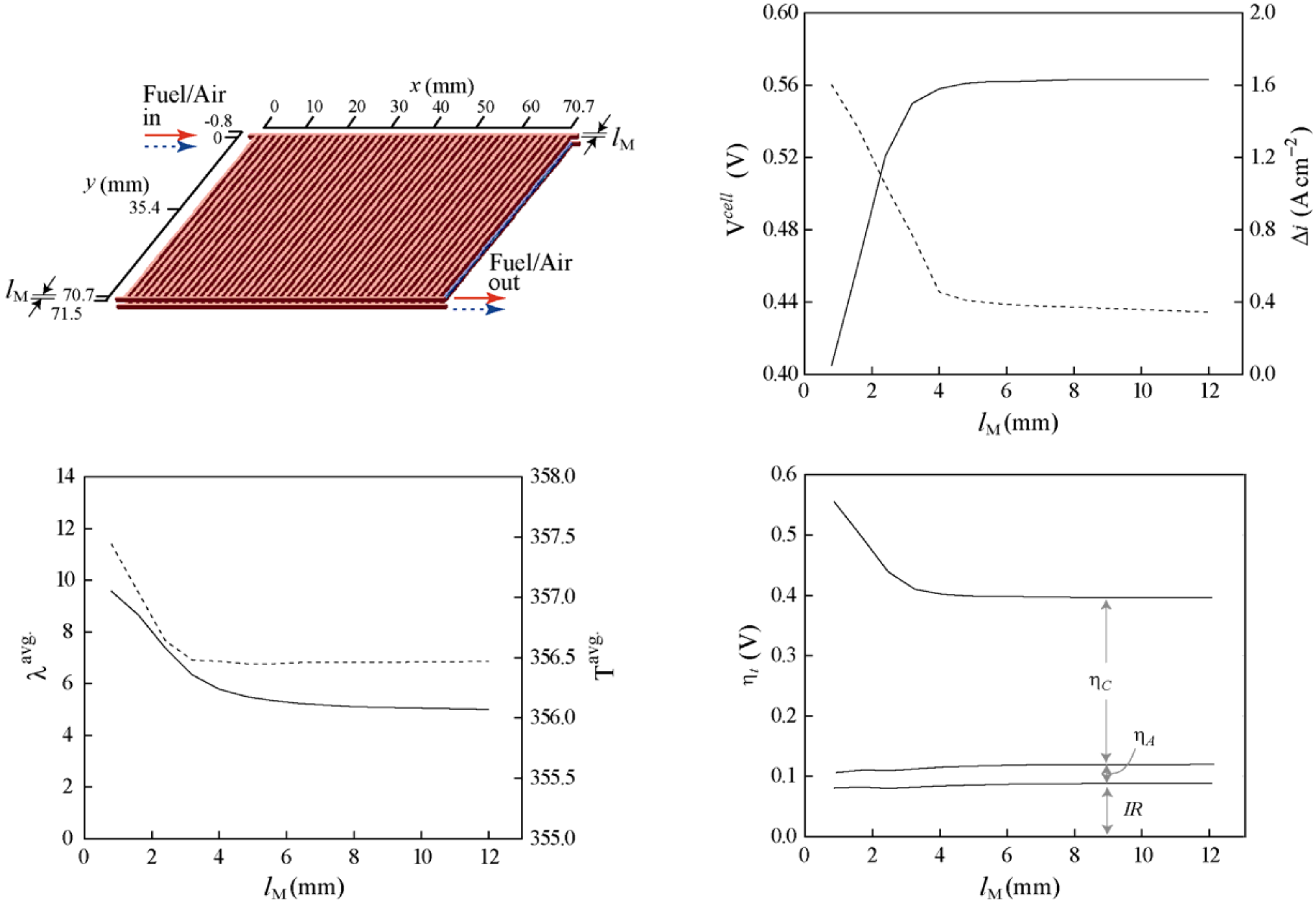
Temperature distribution



Fuel flow at anode channel: conventional cell

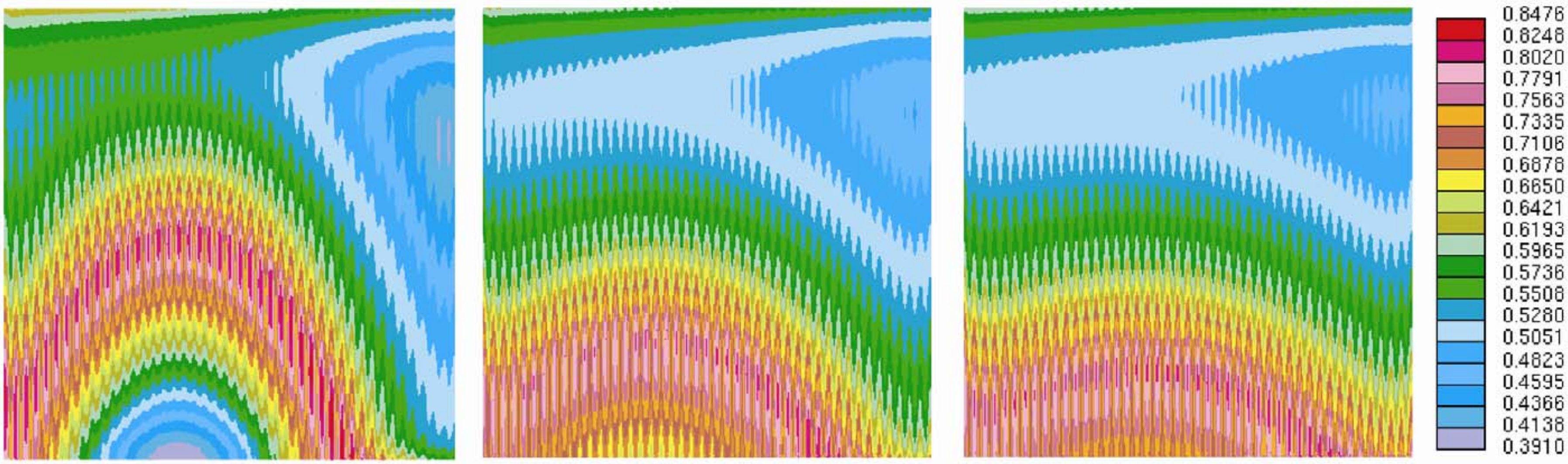


The effect of manifold width (l_M)

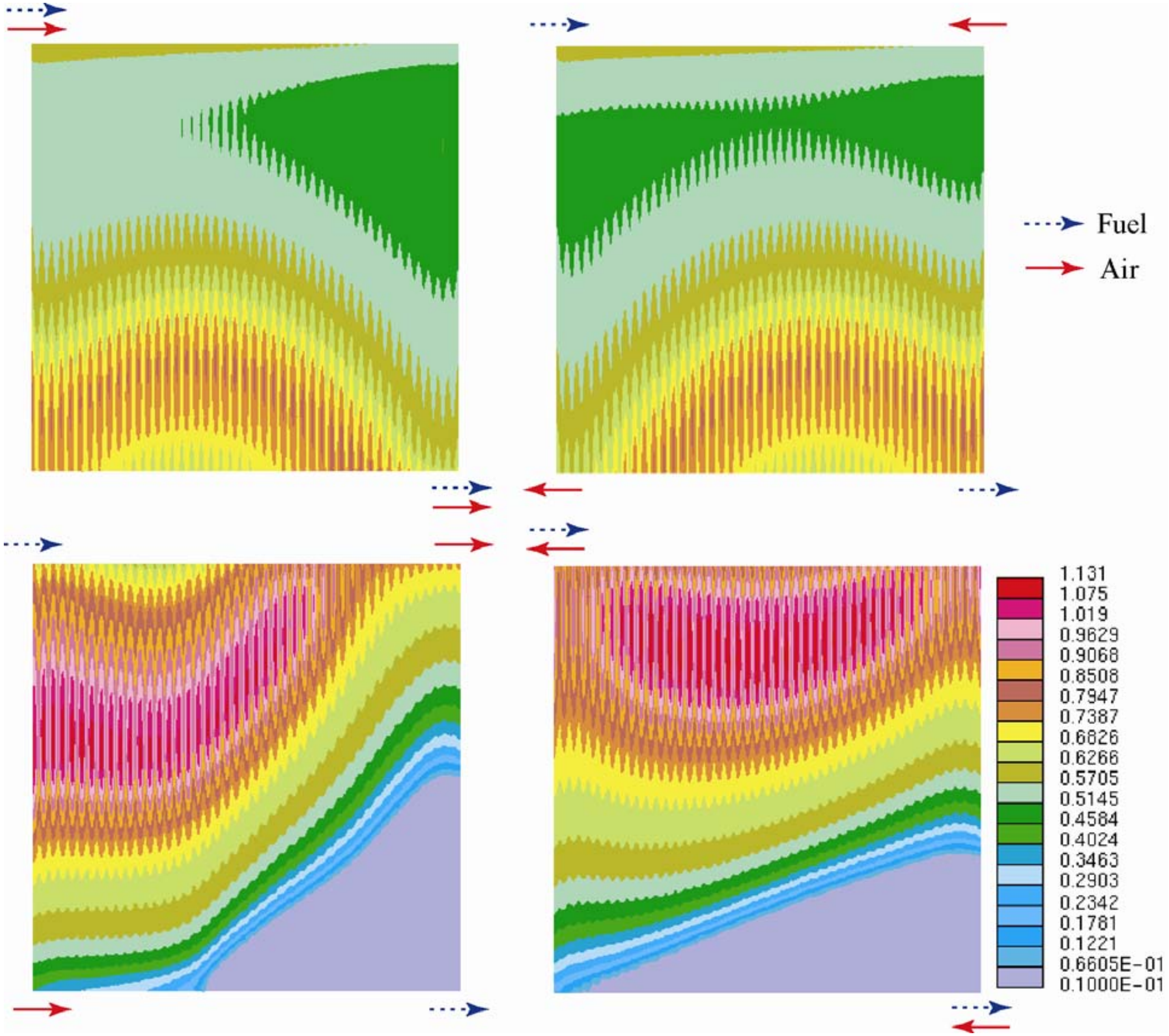


Current density distributions with variations of manifold width (l_M)

$l_M = 4mm$ $l_M = 8mm$ $l_M = 12mm$



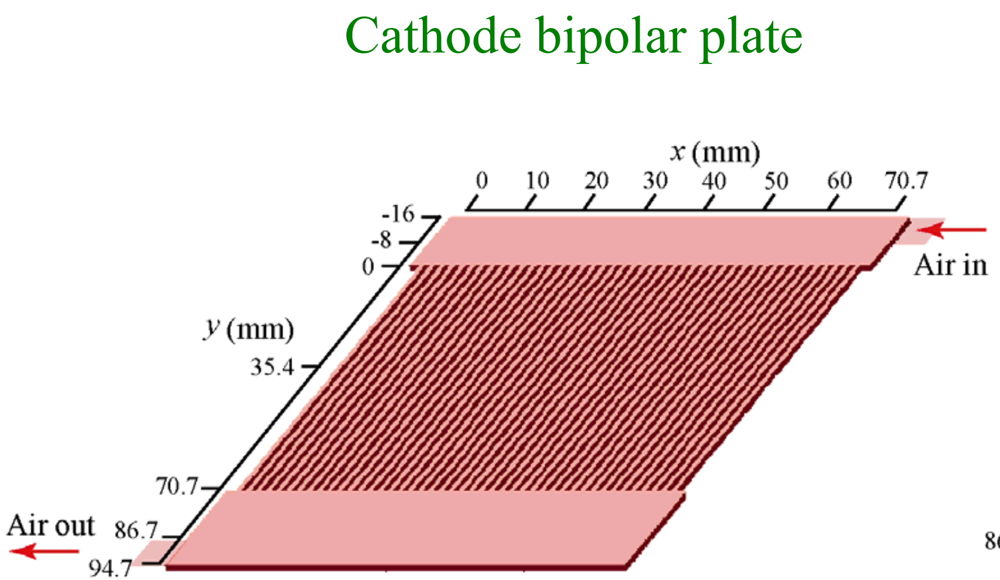
The effect of flow direction on current density distribution

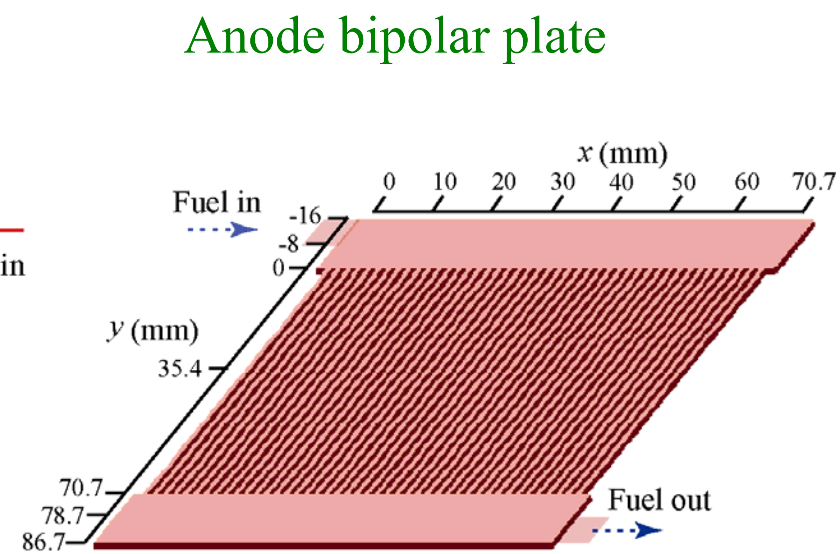


Summary- Analysis of Conventional Cell

- The conventional cell showed low performance and severely non-uniform current density distributions.
- The performance was increased and current density distribution became more uniform with an increase of l_M until 8 mm. However, longer l_M did not show increased performance and only slightly increased the uniformity.
- l_M =8mm and semi co-flow are proposed for an improved cell. The improved cell shows better performance than the conventional cell and less local current density differences. However, this cell still has non-uniform current density distributions due to non-uniform flow profiles.
- Note: the flow profiles are changed with the electrochemical reactions. Thus, optimization should be performed with simulations that consider electrochemical reactions (i.e., use reactive flow conditions rather than cold flow calculations).

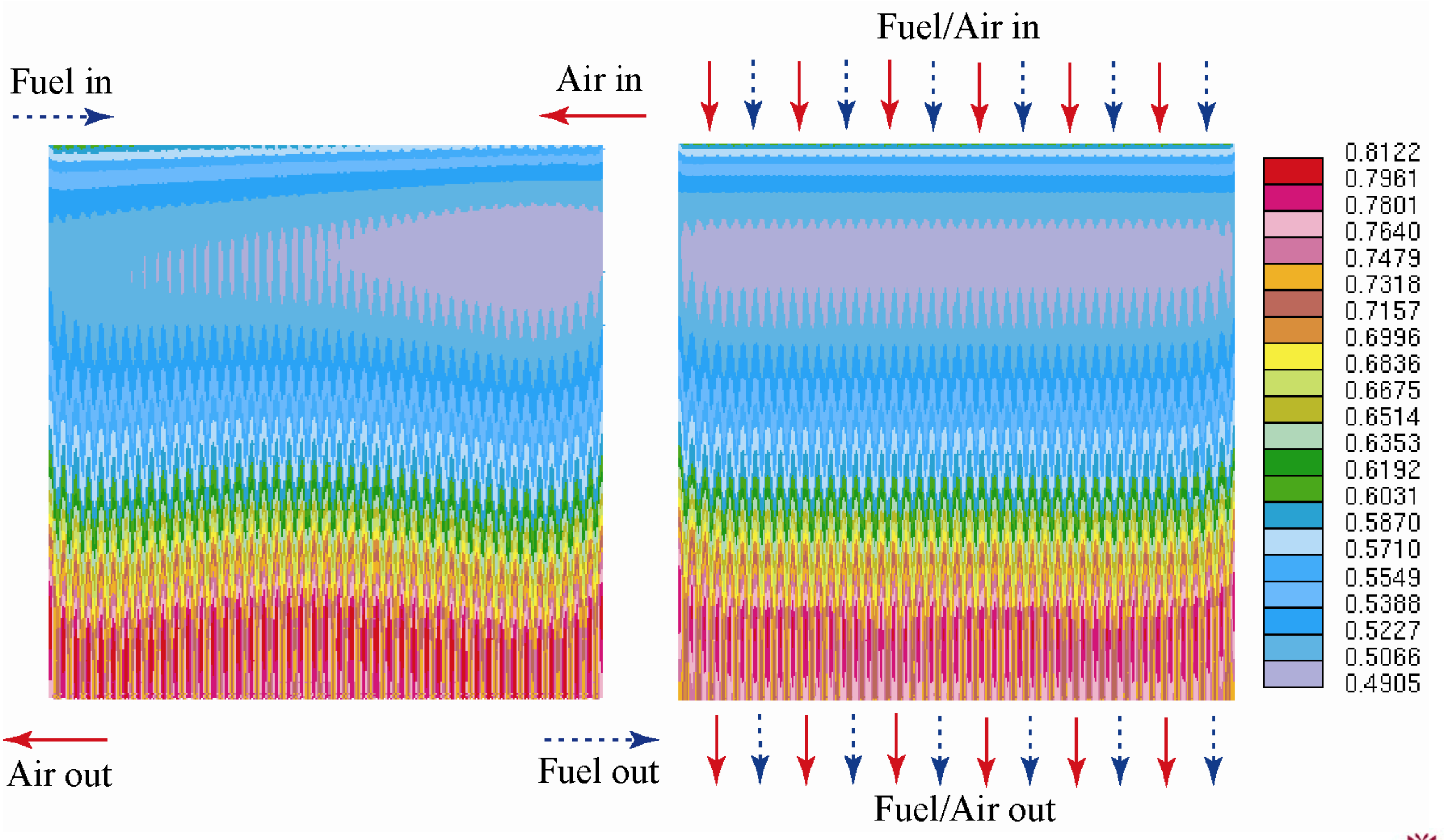
Additional Calculations: Geometry of Optimum Cell



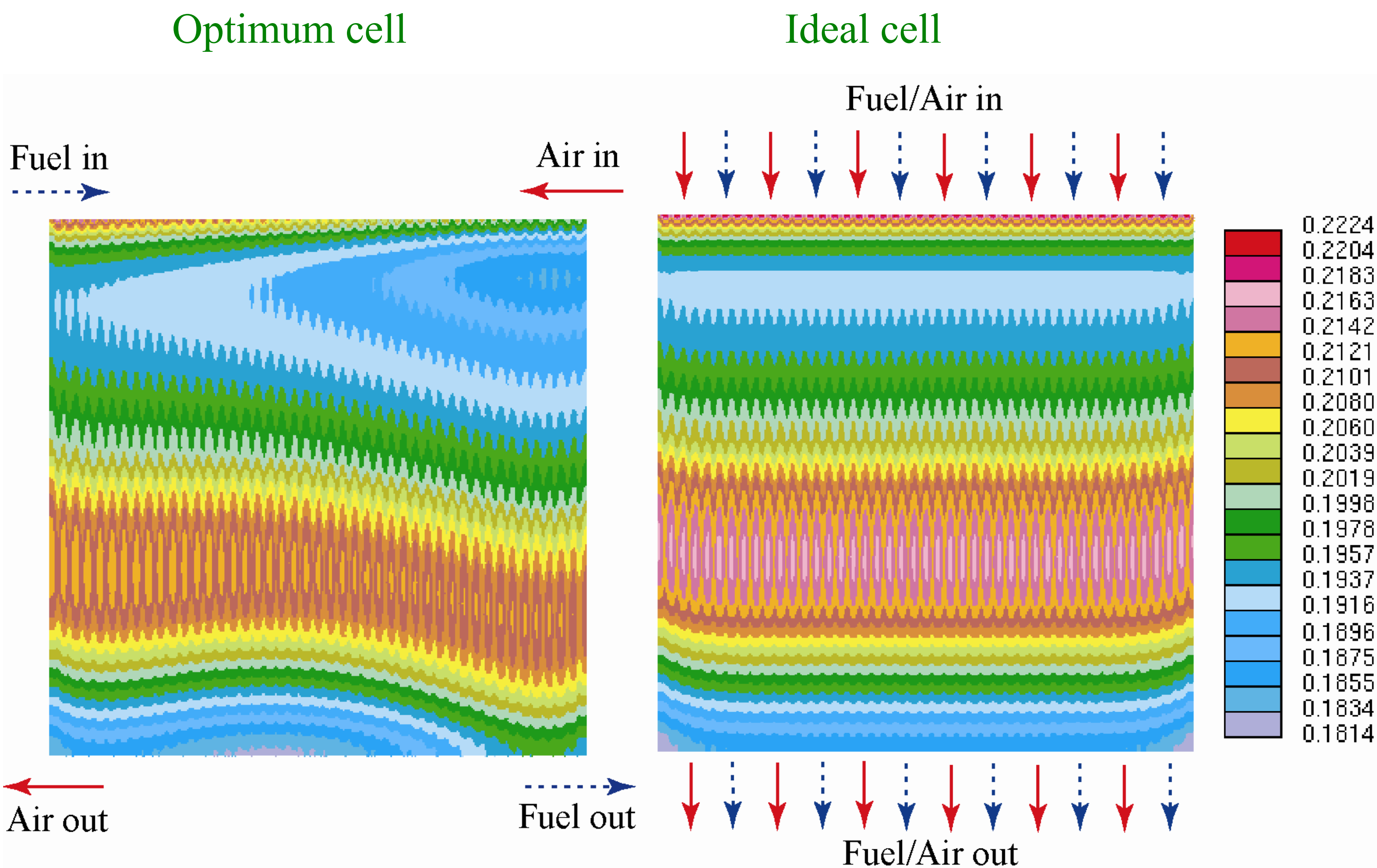


Current density distributions at i=0.6 A/cm^2

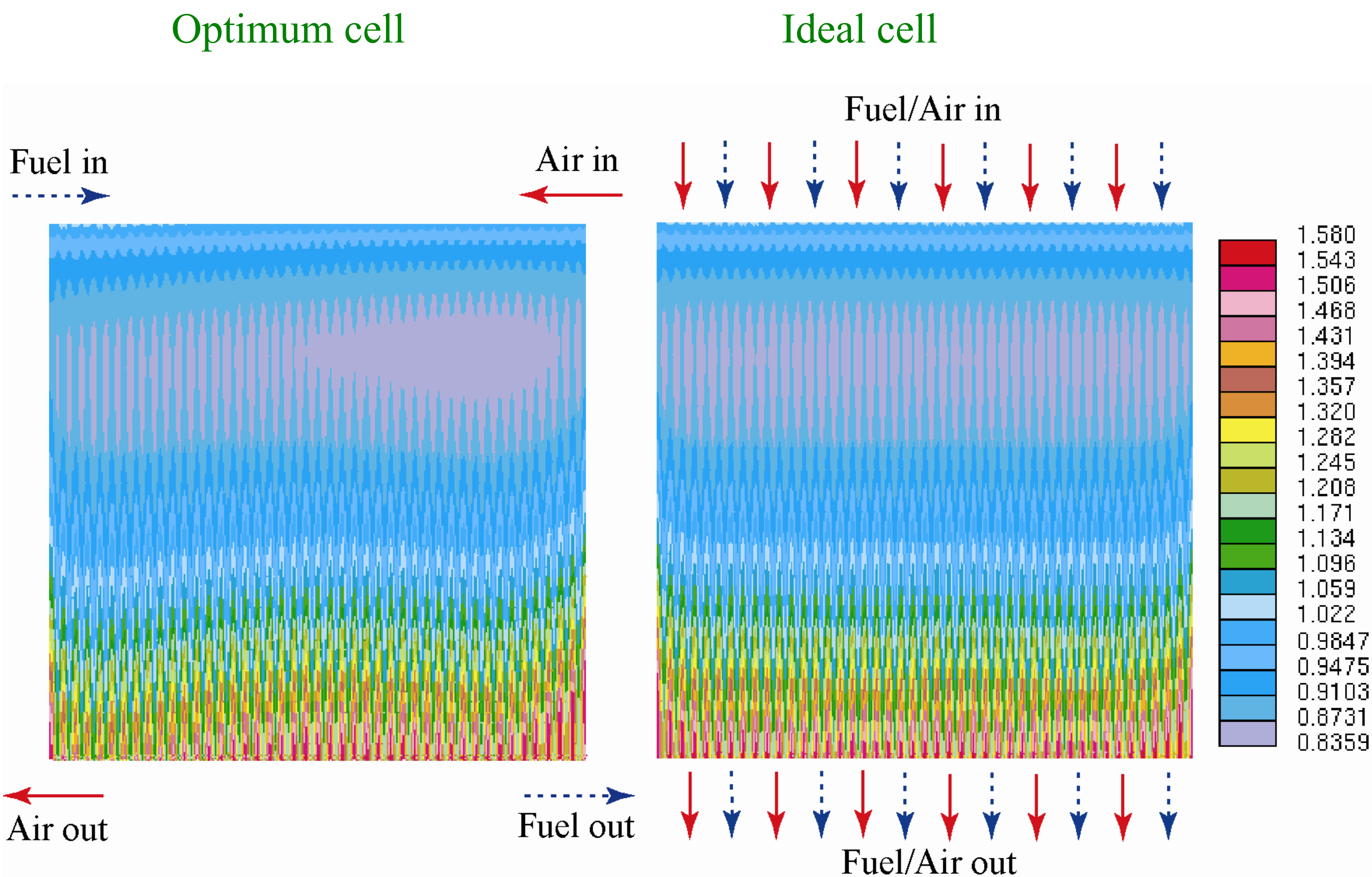
Optimum cell   Ideal cell



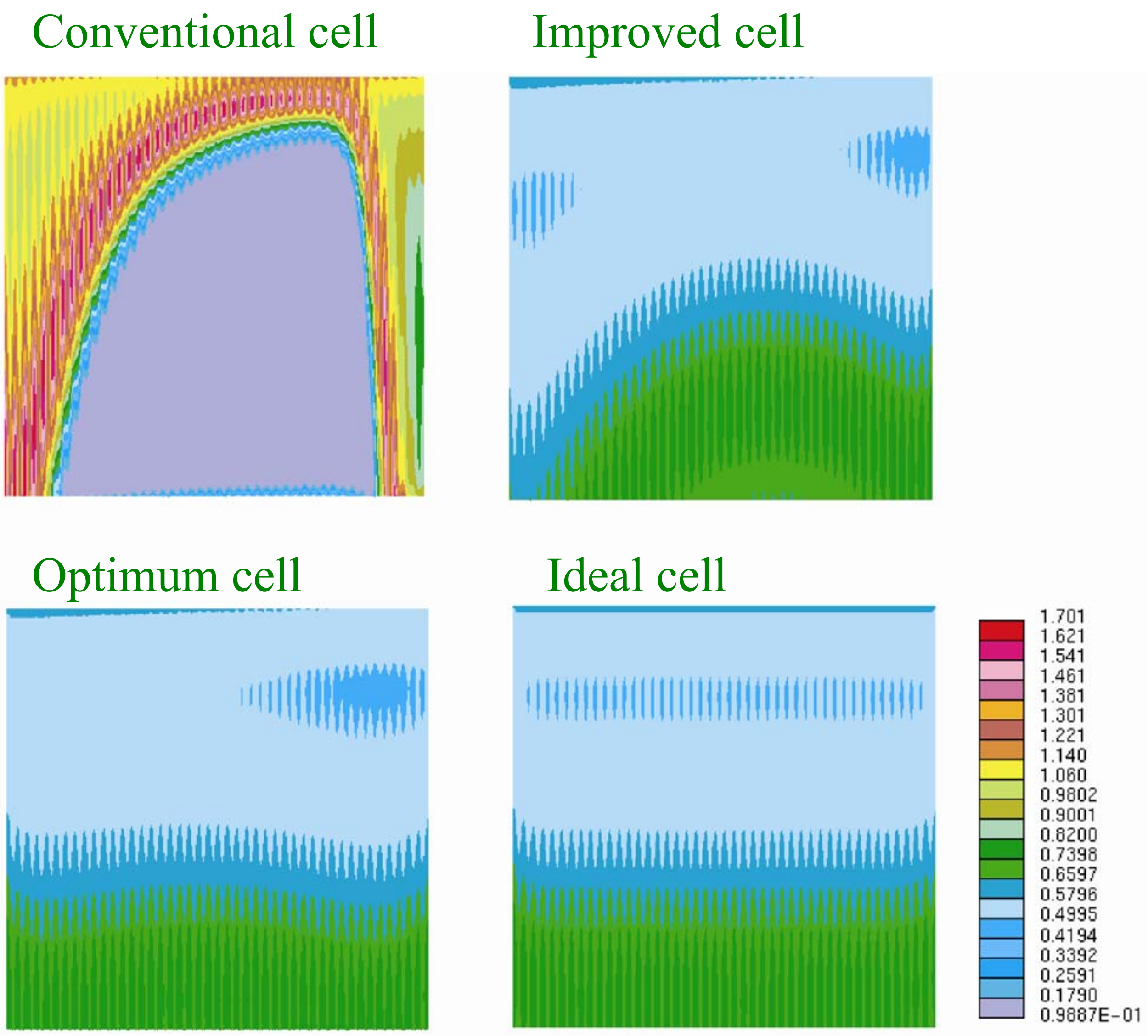
Current density distributions at i=0.2 A/cm^2



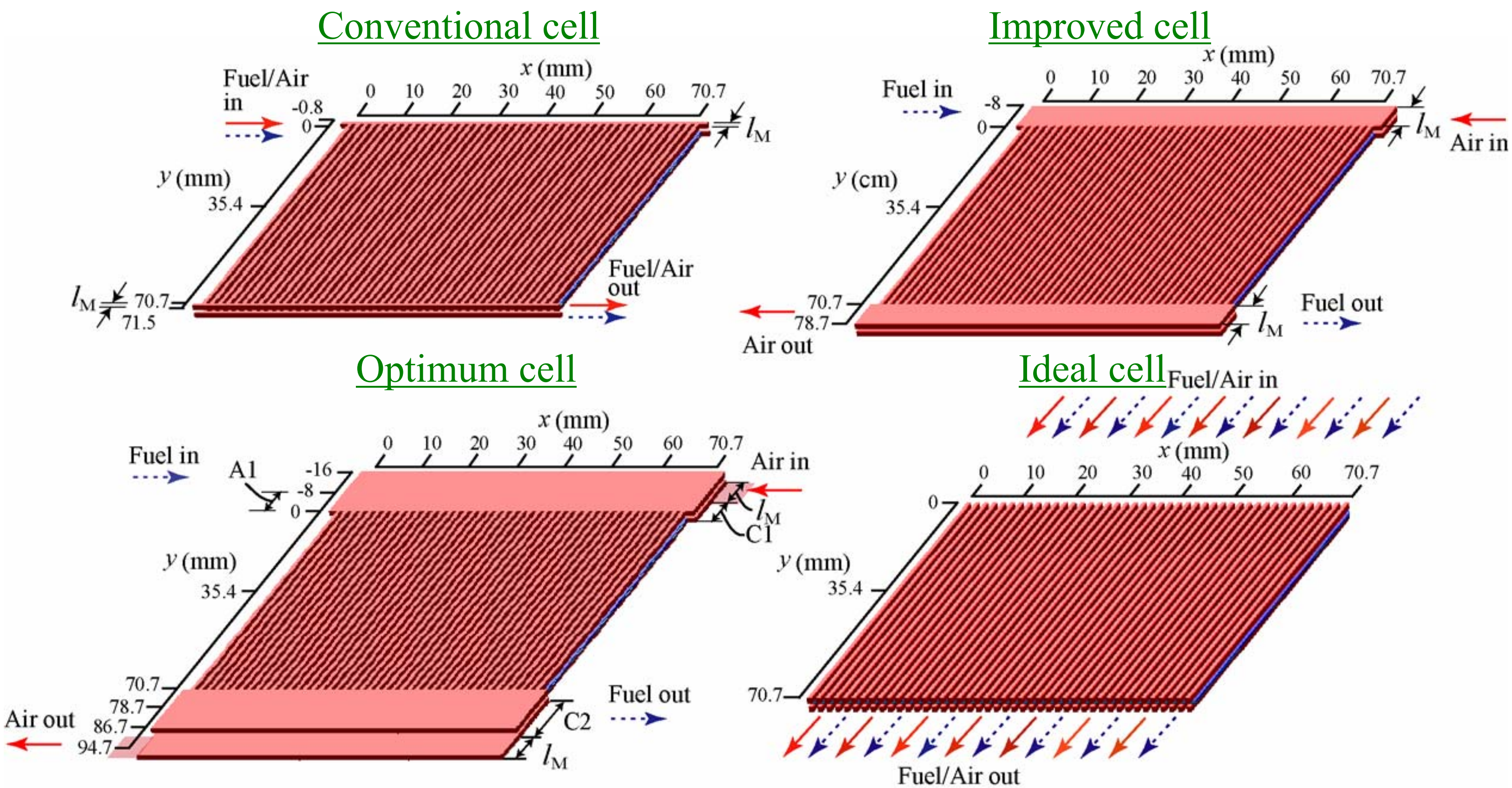
Current density distributions at i=1.0 A/cm^2



Current density distributions (0.6 A/cm^2)



Comparison of Improved & Optimized Cells at 0.6 A/cm^2



	C1(mm)	C2(mm)	l_M(mm)	A1(mm)	V^{cell}(V)	Δi(Acm^{-2})	λ_{avg}	T_{avg}(K)	ΔT(K)
Conventional Cell	0	0	0.8	0	0.405	1.602	9.57	357.44	12.62
Improved Cell	0	0	8	0	0.563	0.324	5.065	356.45	4.08
Ideal Cell	N/A	N/A	N/A	N/A	0.566	0.304	5.151	356.47	4
Optimum Cell	8	16	8	8	0.563	0.322	4.969	356.48	4.06

Project 2, Task 2 Conclusions

- The optimum cell showed uniform flow profiles and symmetric current density distributions similar to ideal cell, at 0.6 A/cm^2. However, non-uniform flow profiles which lead to un-symmetric current density distributions were observed at lower and higher current densities. These were mainly caused by different inlet velocities.

- The optimum cell showed similar current density distributions and slightly lower performance than the ideal cell. It showed more uniform flow profiles than improved cell. Also, the optimum cell had significantly higher performance and more uniform current density distributions than conventional cell because optimization of the geometry leads to more uniform flow profiles.

Summary

- Projects just started
- All Projects involve interaction with industry
- Results from Project 2: H2 Quality
  - has implications for existing data and experimental procedures
  - results to be assessed with H2 quality team