



等离子体点火助燃 研究进展与展望

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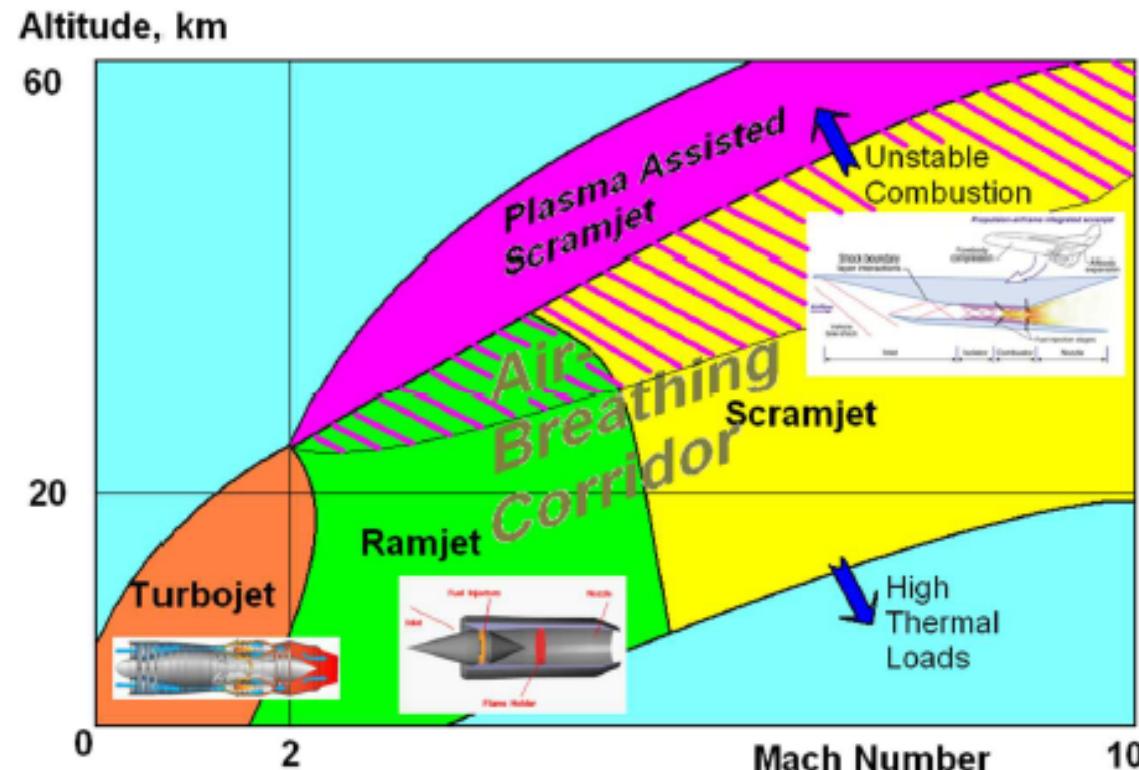


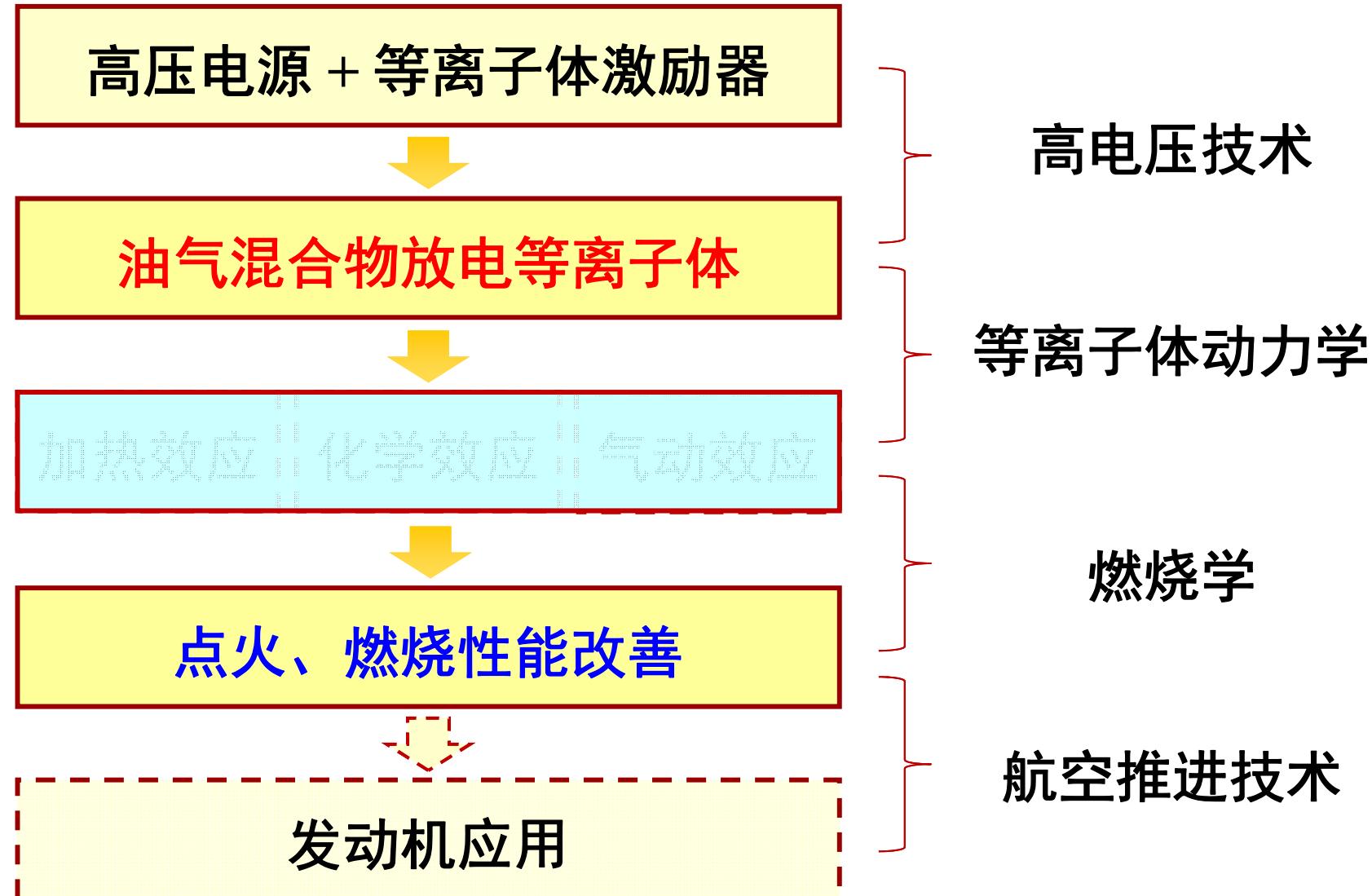
一、进展、前沿与难点

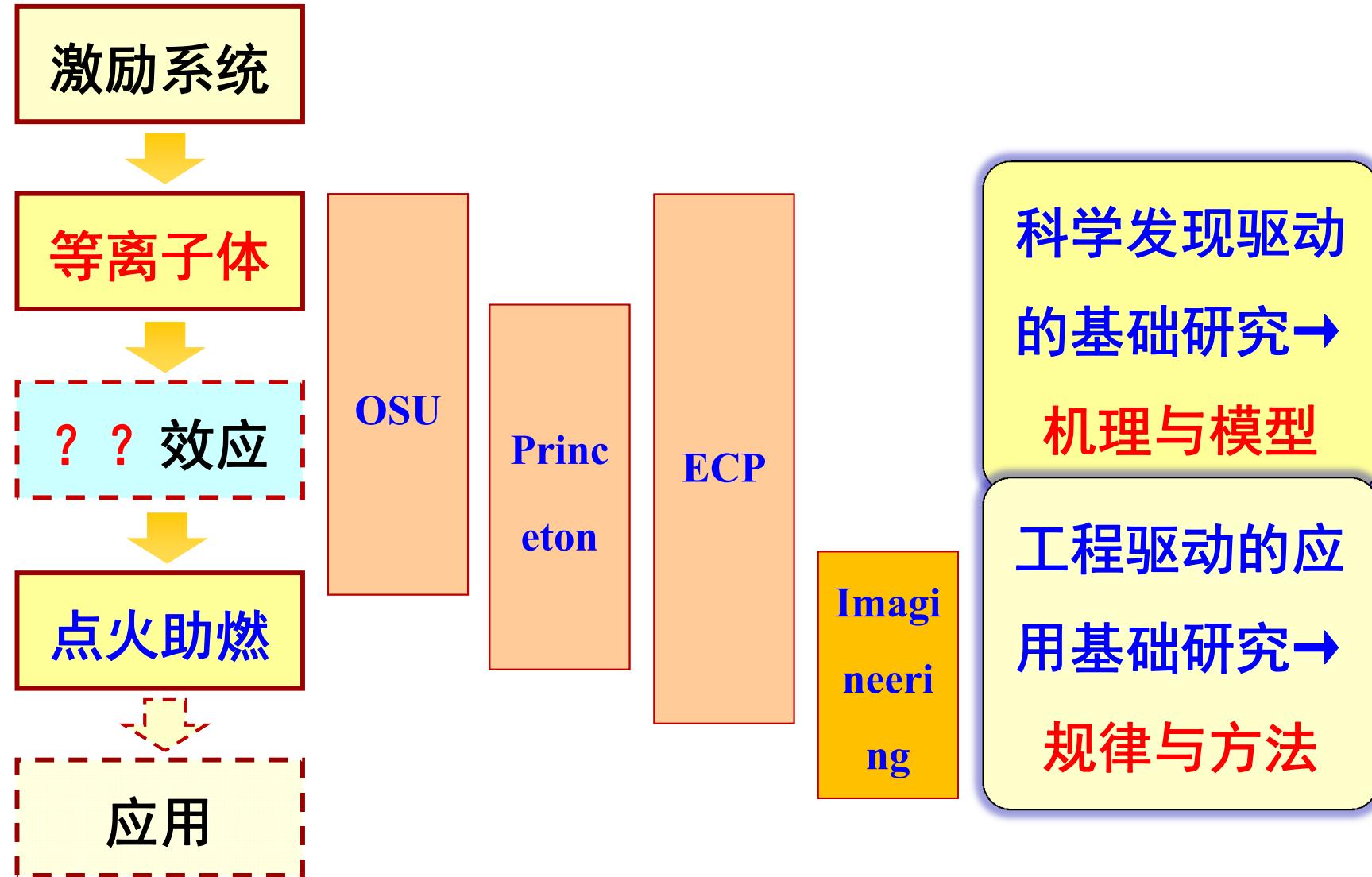
二、未来可能的研究方向与合作



- 民用发动机：节能、减排，贫油燃烧、低温燃烧
 - 军用发动机：拓宽边界（极端条件—压力、温度、速度）、简化结构（取消补氧、火焰稳定器）









MURI: Fundamental Mechanisms, Predictive Modeling, and Novel Aerospace Applications of Plasma Assisted Combustion (2009-2014)

- The Ohio State University (Igor Smirnov)
- Princeton University (Yiguang Zhou)
- Princeton University (Richard M. Gord)
- Princeton University (Andrey Sazonov)
- Pennsylvania State University (Eduardo P. Oñate)
- Georgia Institute of Technology (John M. Tuck)
- Ecole Polytechnique (Svetlana S. Savenkov)
- Moscow State University (Nikolay V. Kondratenko)
- Moscow Institute of Physics and Technology (Andrey S. Sazonov)
- Ecole Centrale (Christophe Laux)

1、宽广条件下的非平衡等离子体动力学实验数据与机制（温度：300-1800K，压力：0.1-70bar）

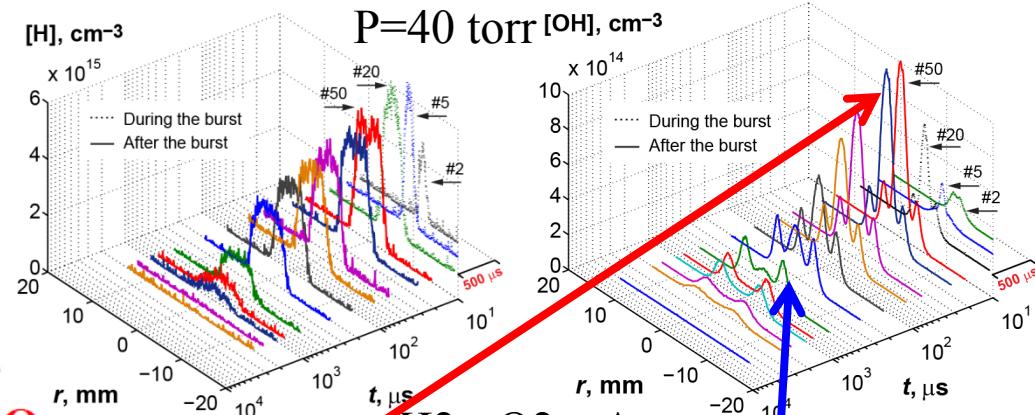
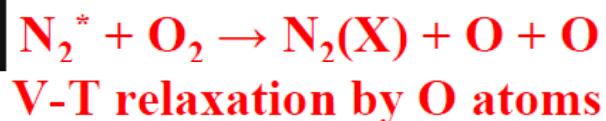
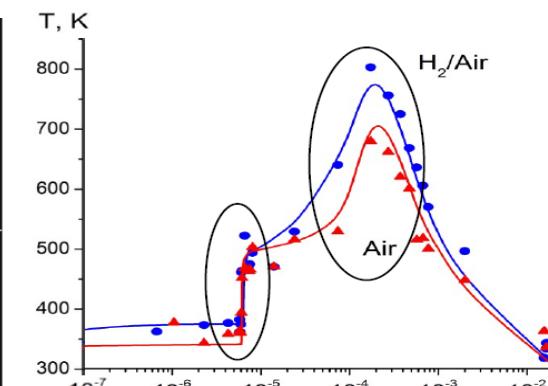
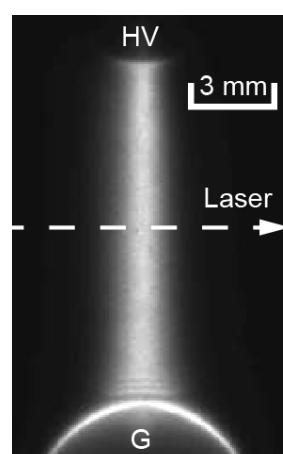
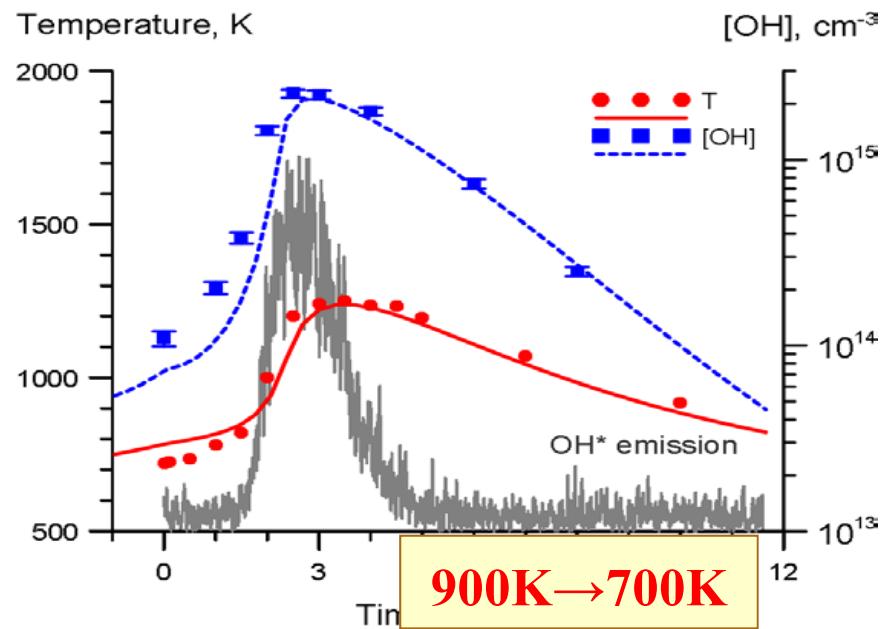
2、纳秒脉冲、直流/射频、微波等离子体对点火延迟、火焰稳定与层流火焰速度影响的实验数据

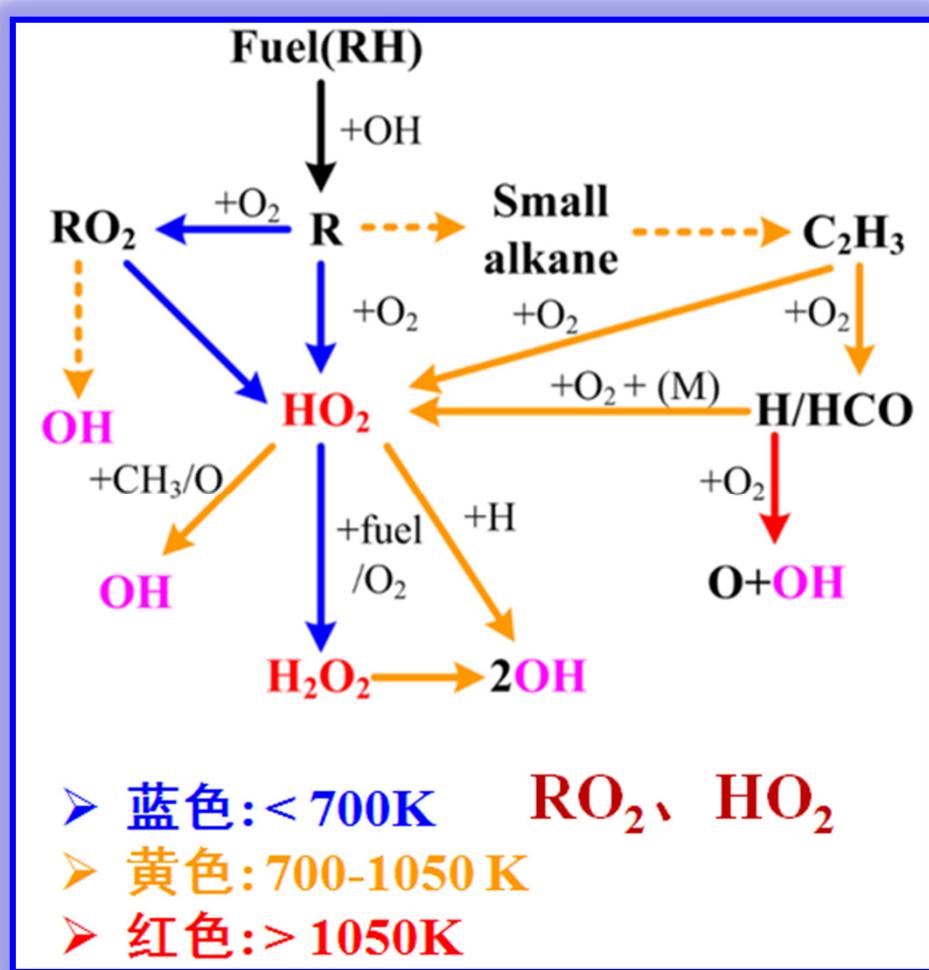
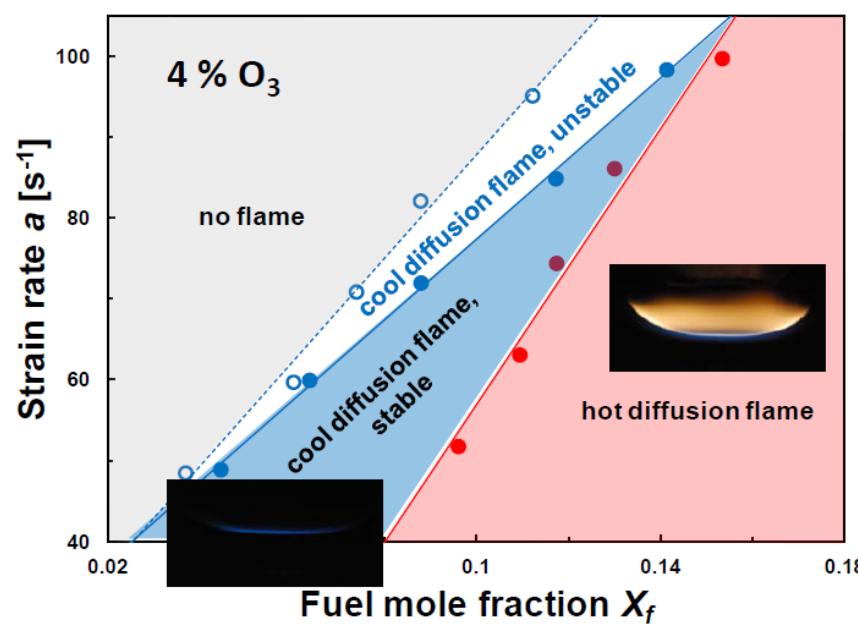
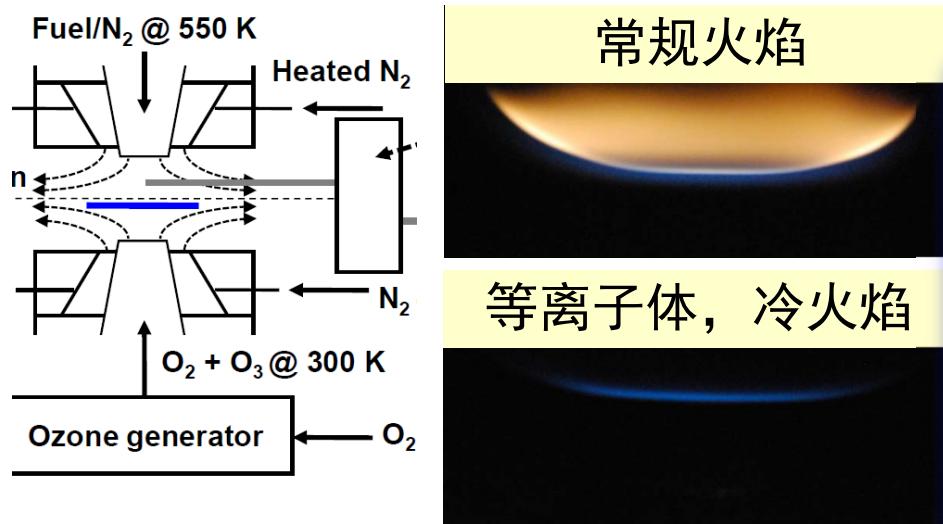
3、高精度仿真程序



$\text{H}_2/\text{C}_1\text{-C}_3\text{-air}$
 $P=50\text{-}500\text{torr}$

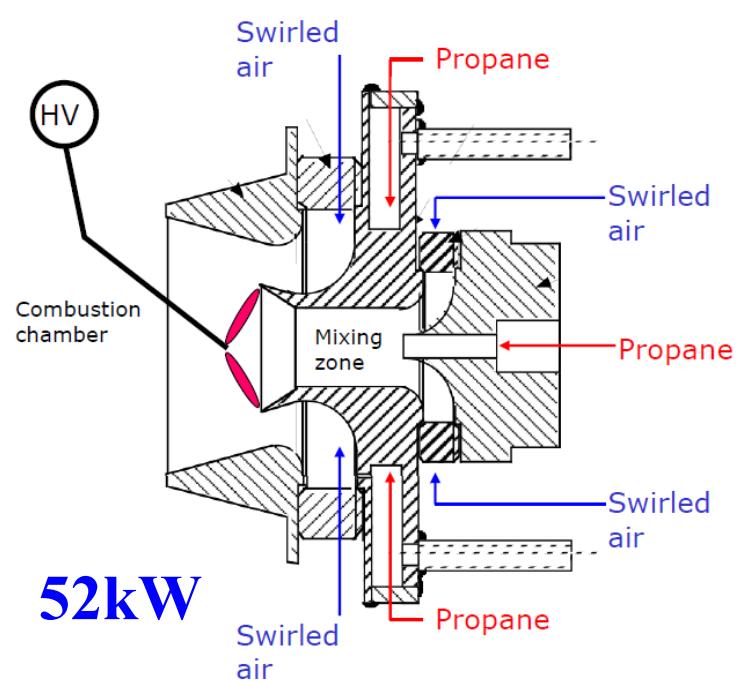
- 电场强度
- 电子温度与密度
- 转动温度
- 振动能级分布
- O、H、OH、NO等







ECP-Laux: 基于纳秒脉冲等离子体的贫油燃烧



Without plasma



$2.1 \text{ m}^3/\text{h}$
 $\Phi=0.47$



$1.95 \text{ m}^3/\text{h}$
 $\Phi=0.44$



$1.8 \text{ m}^3/\text{h}$
 $\Phi=0.4$

Extinction
 $\Phi = 0.4$

With plasma, 30 kHz



$2.1 \text{ m}^3/\text{h}$
 $\Phi=0.47$



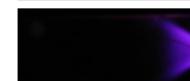
$1.95 \text{ m}^3/\text{h}$
 $\Phi=0.44$



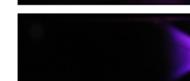
$1.8 \text{ m}^3/\text{h}$
 $\Phi=0.4$



$1.65 \text{ m}^3/\text{h}$
 $\Phi=0.37$



$1.35 \text{ m}^3/\text{h}$
 $\Phi=0.3$



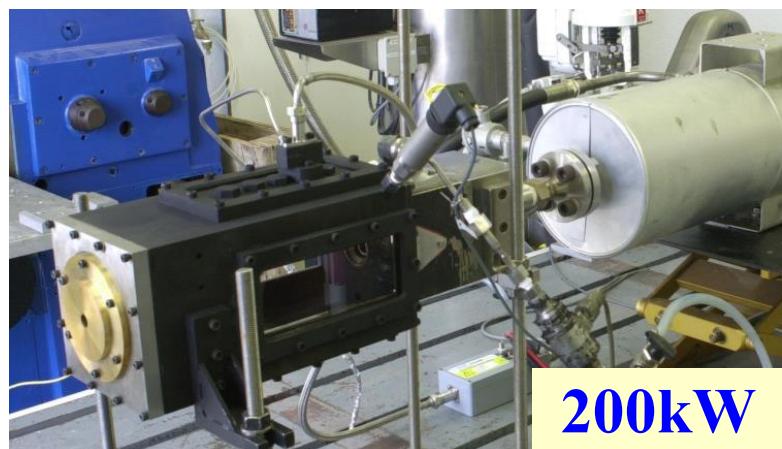
$1.2 \text{ m}^3/\text{h}$
 $\Phi=0.27$



$1.05 \text{ m}^3/\text{h}$
 $\Phi=0.23$

Gain 70%

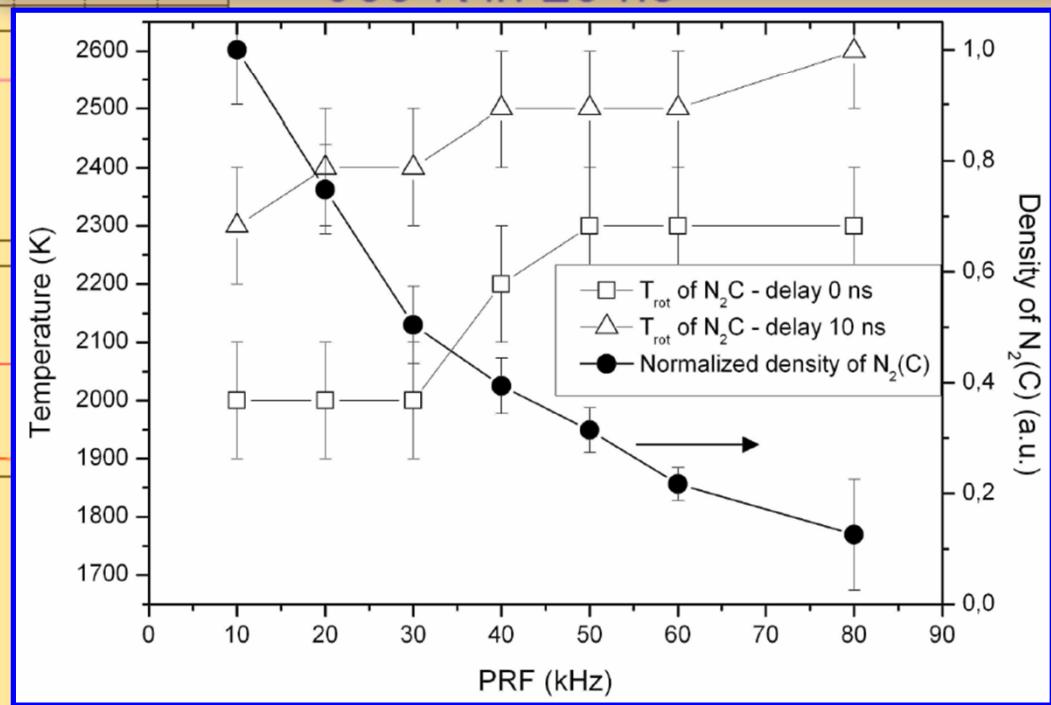
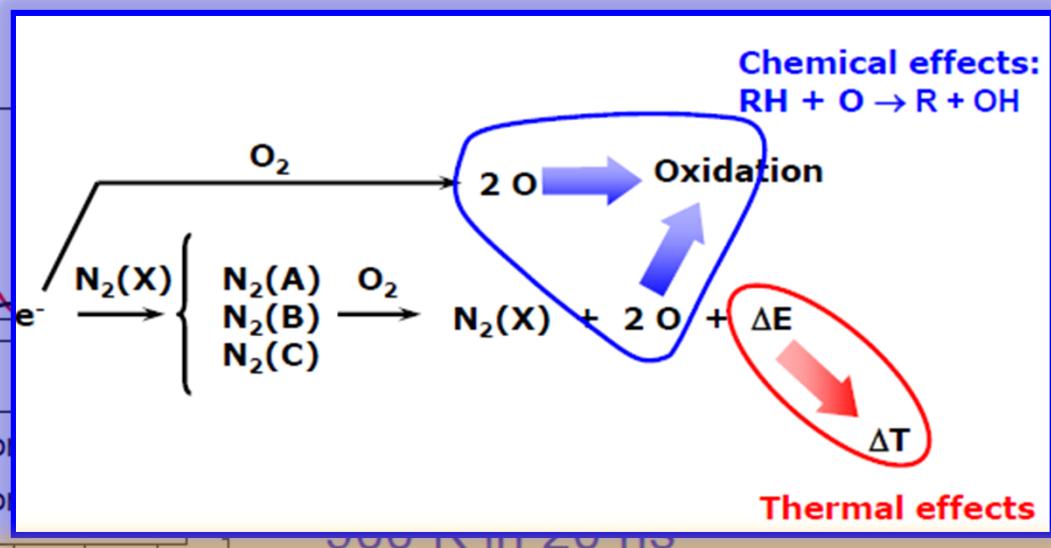
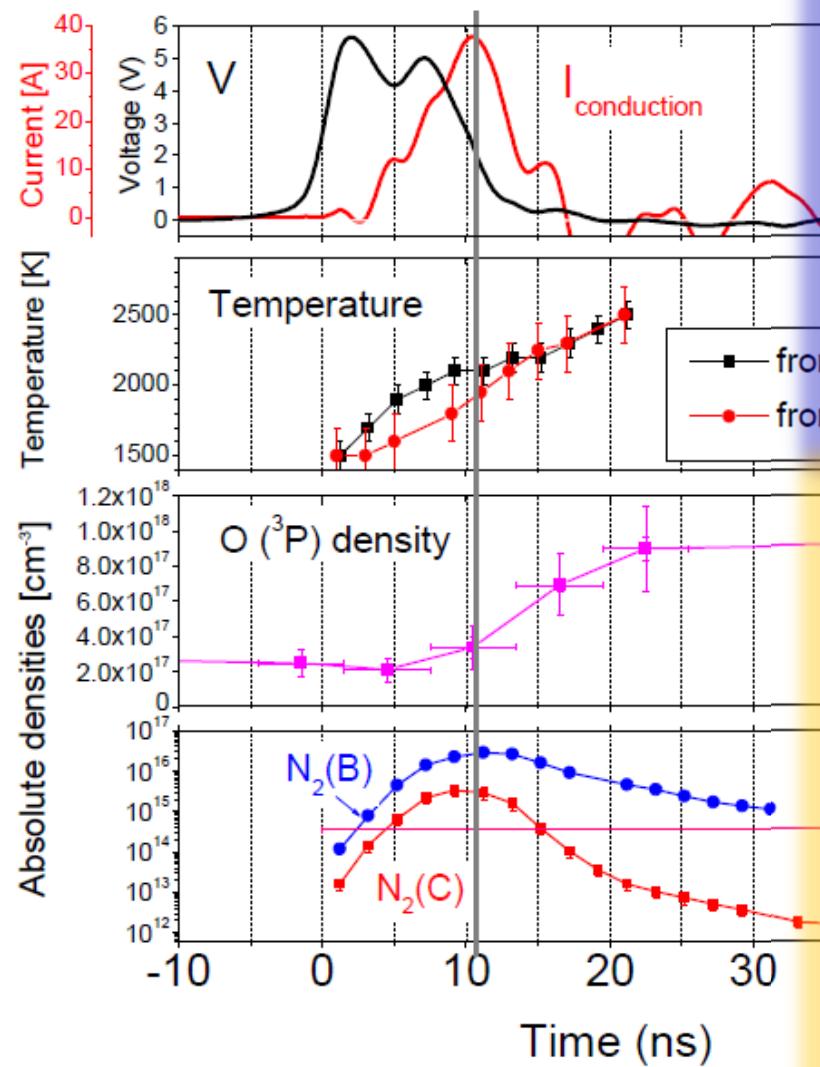
Extinction with plasma
 $\Phi=0.11$

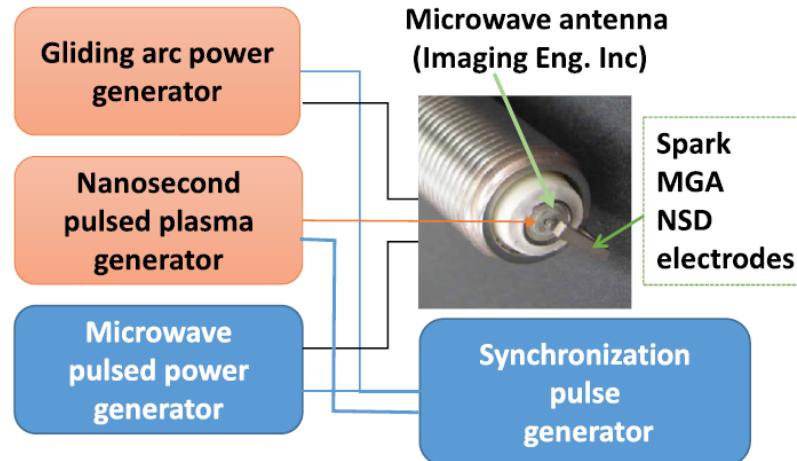


- 煤油-空气, 3bar
- 纳秒放电, 100kHz
- 小于火焰功率1%
- $0.44 \rightarrow 0.21$ (52%)

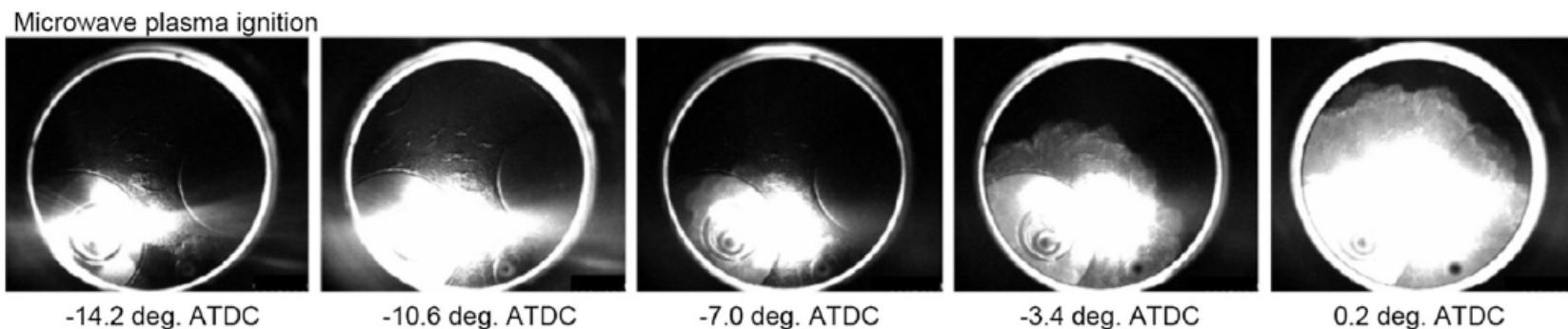
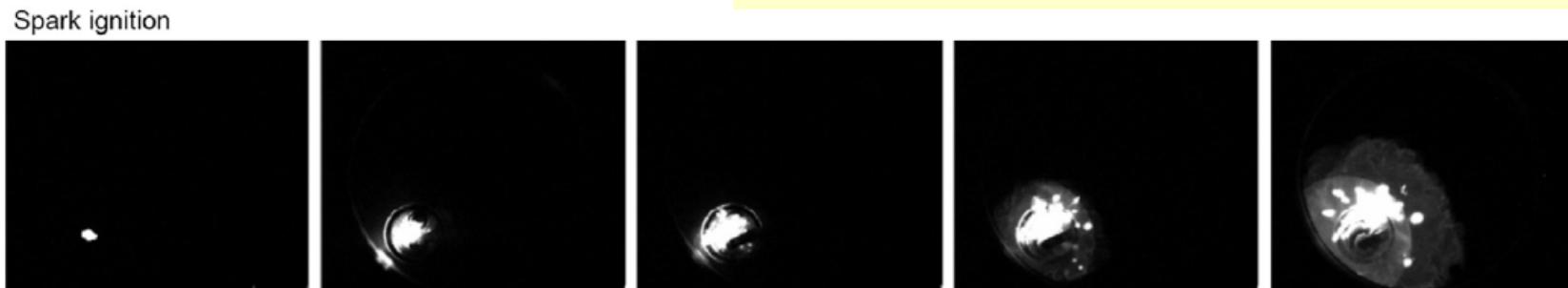


ECP-Laux: 基于纳秒脉冲等离子体的贫油燃烧





预期可以在丰田、福特等汽车发动机上应用，显著降低耗油率和排放，成本在100美元以内。



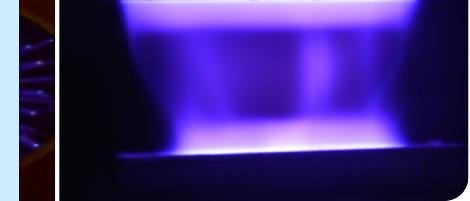


国内的已有工作

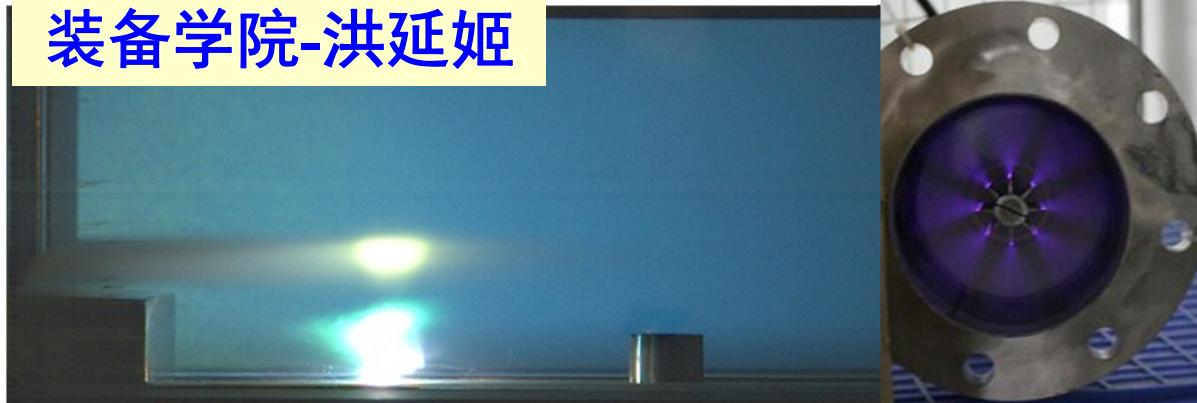


- 点火边界扩大27.8%
- 点火延迟时间缩短60%
- 稳定燃烧范围扩大16%

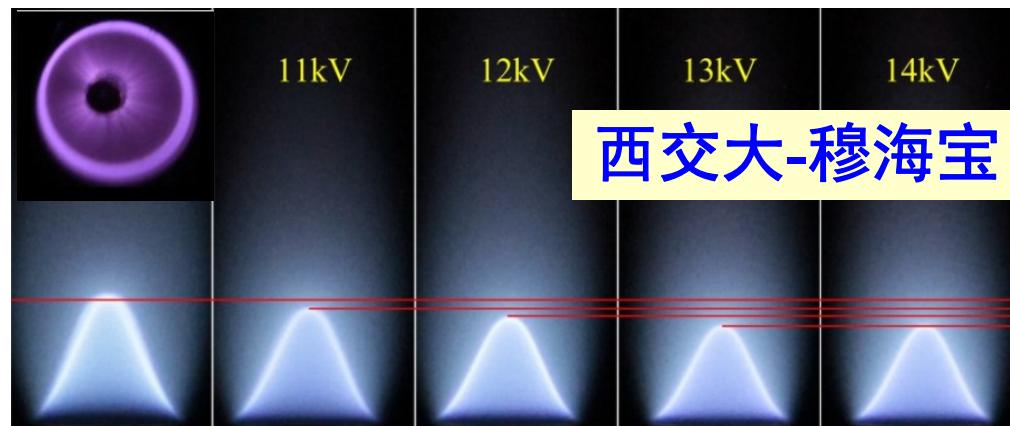
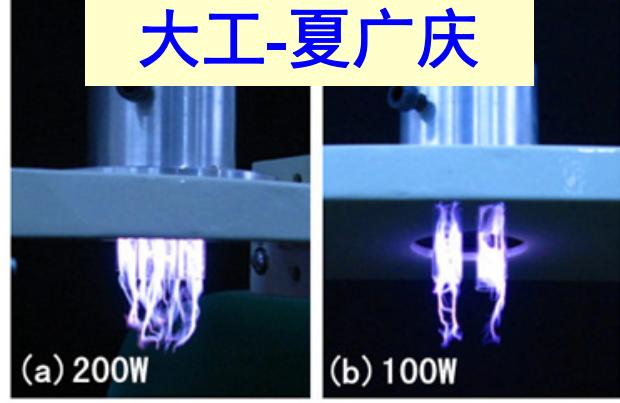
空工大-何立明



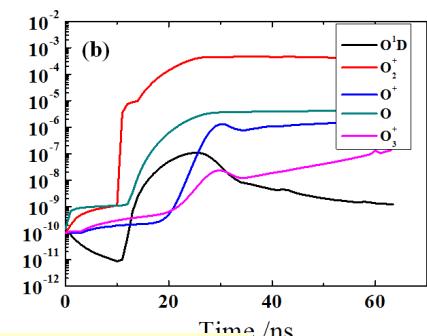
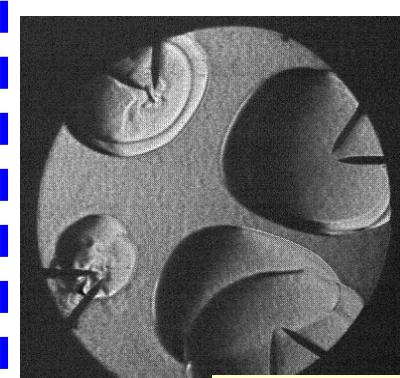
装备学院-洪延姬



大工-夏广庆



西交大-穆海宝



空工大-吴云

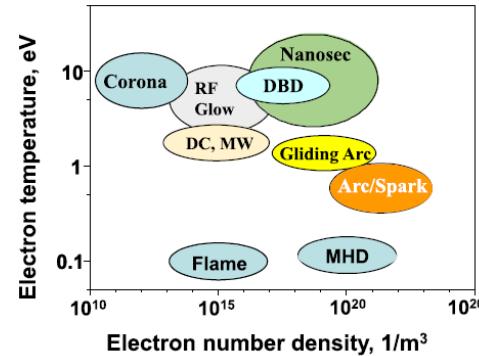
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激励系统



等离子体



✓ 原理实验装置

✓ E 、 Ne 、 Te 、 Tv

？？效应



✓ 快速加热, O 、 H 、 OH 、 RO_2 、 HO_2

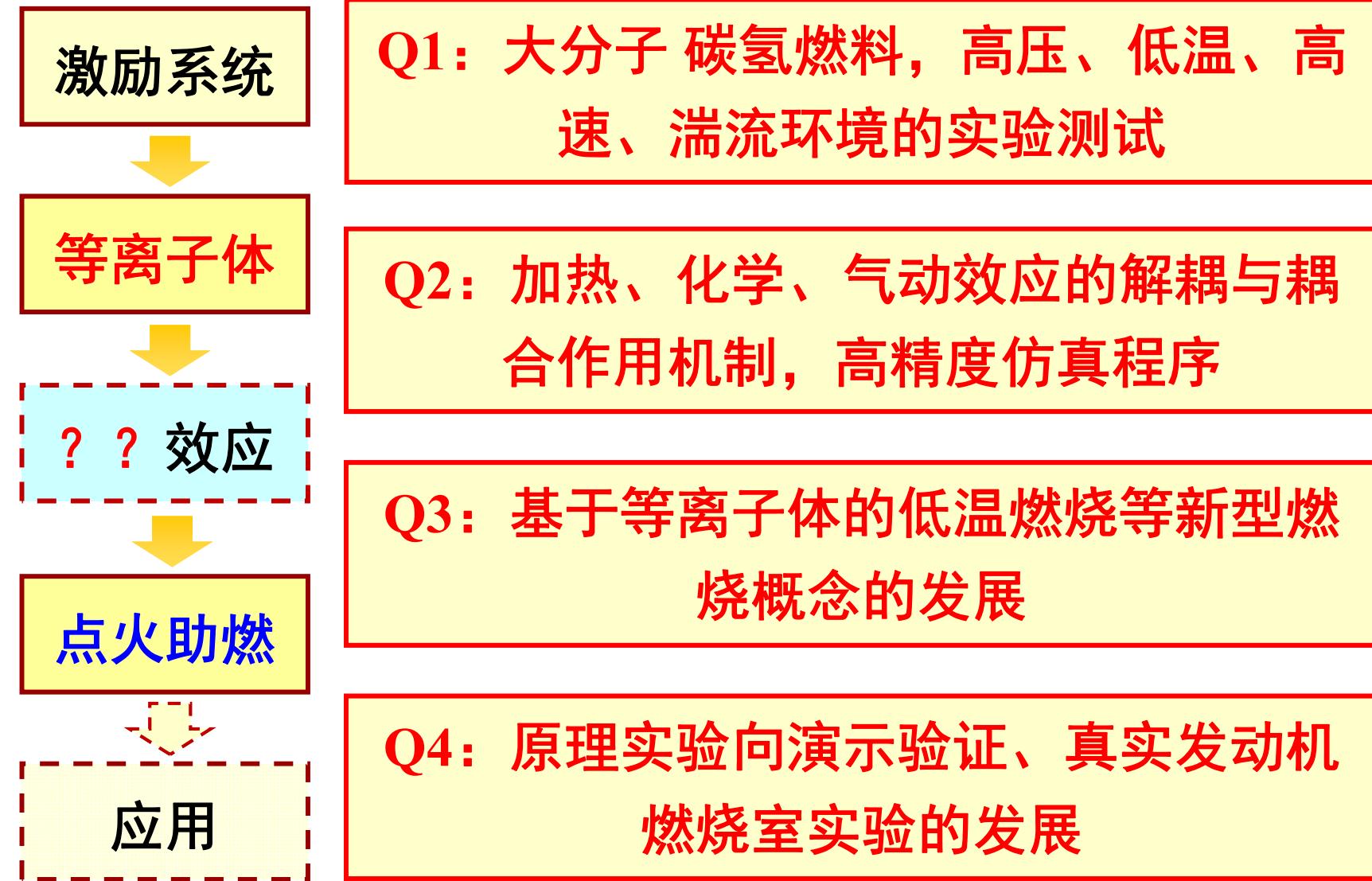
点火助燃



应用

✓ 低温燃烧, 贫油燃烧, 缩短点火延迟, 提高熄火流速, 抑制热声不稳定, ...

✓ 燃烧室实验





一、进展、前沿与难点

二、未来可能的研究方向与合作



- **坐标系**：OSU、Princeton、ECP等一流机构的平台和结果，**科学发现导向**
- **现状**：等离子体动力学与燃烧学的交叉合作不够，激光测试与诊断的研究基础薄弱
- **建议**：抓住机遇，发挥我国的**基础和优势**，设计建设**benchmark实验台**（controlled, well-characterized），加强**交叉合作**，**细致校验**，**有限目标集中突破**
- **困难**：门槛高、难度大、周期长



- **坐标系**：我国民用、军用发动机发展中的重要燃烧问题，**工程背景导向**
- **现状**：等离子体射流的效果有限、功耗很大，高效等离子体点火助燃激励的发展缓慢，交叉合作不够
- **建议**：以**重大需求**为牵引，**集成**国际上的科学进展，**反推**需要进一步解决的科学与技术问题，加强**交叉合作**，**有限目标**集中突破
- **困难**：试凑的盲目性，难度大



谢谢大家！

欢迎到实验室指导交流！