Preliminary studies on LSB flames under active-grid-generated turbulence and actively modulated secondary swirl flow

Shigeru TACHIBANA*, Laurent ZIMMER, Junji SHINJO and Satoru OGAWA

Institute of Aerospace Technology

Japan Aerospace Exploration Agency (JAXA)

*e-mail: tachibana.shigeru@jaxa.jp

10th International Workshop on Premixed Turbulent Flames, August 12- 13, 2006, Mainz, Germany

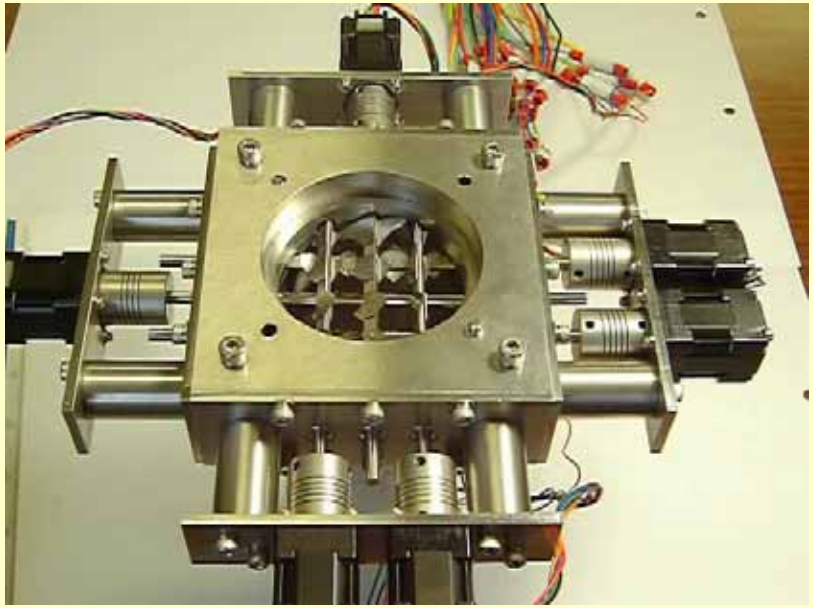
1. Active-grid LSB

(to get intense grid turbulence)

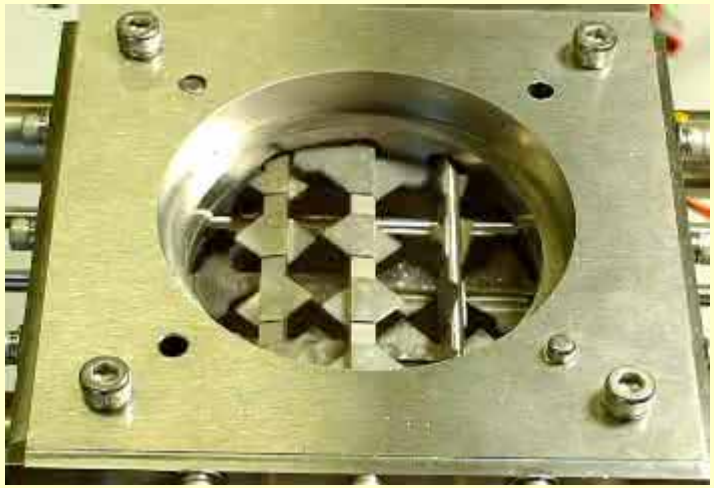
2. Active-swirl LSB

(to see the flame response)

Active grid adapted to the LSB



Speed = 0.5 rps, Period = 250 pulses (90 deg)

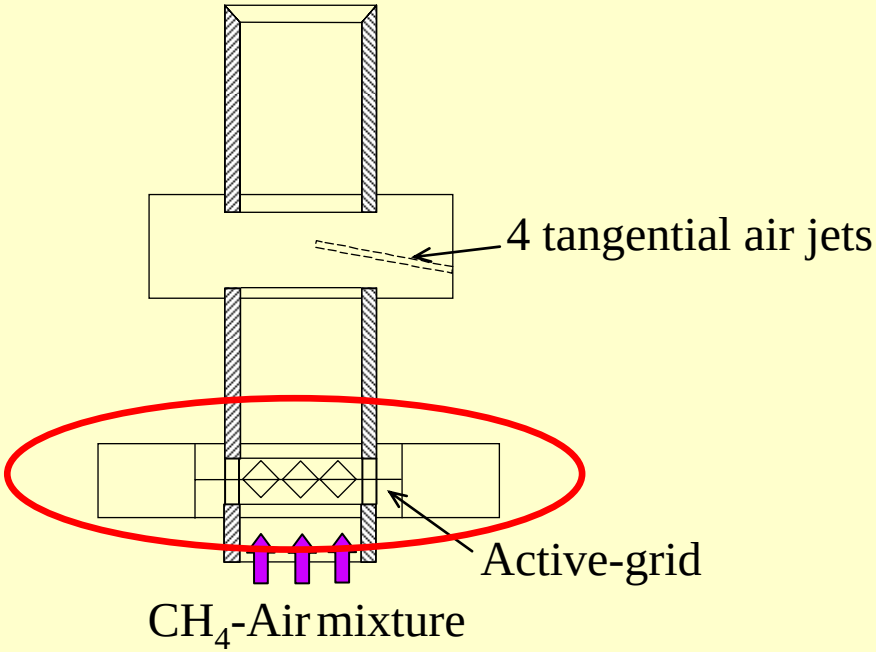


(Click for movie)

Speed = 2 rps, Period = random mode

	Rotating speed	Rotating direction	Switching period
Makita (1991)	Fixed (2 rps)	Random	N/A
Mydlarski & Warhaft (1996)	Fixed (2 rps)	Random	O(0.1 sec)
Larssen & Devenport (2003)	Random	Alternative	Random
Kang et al. (2003)	Random (3.5 ~ 7 rps)	Random	1 sec
Present study	Random (1~2 rps)	Random	O(0.1 sec)

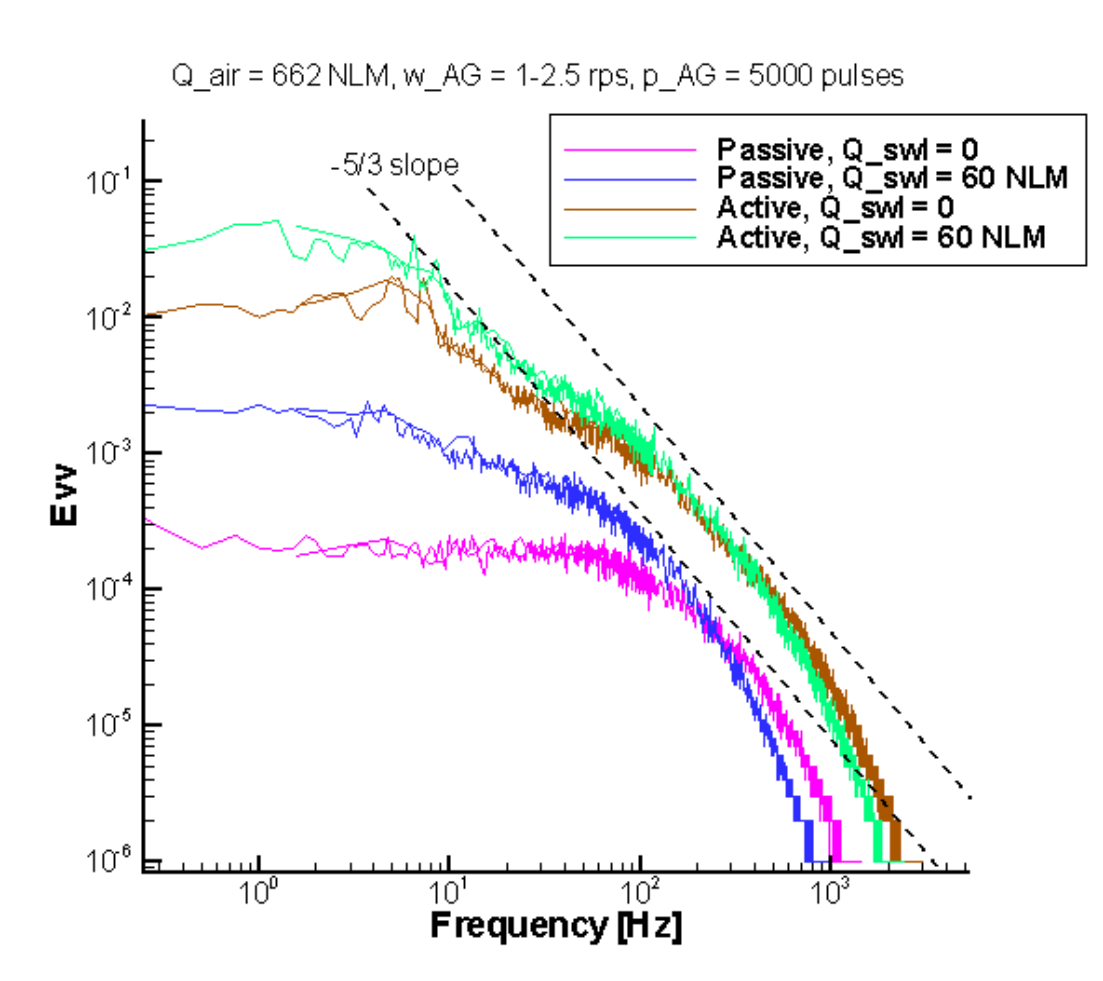
Active grid adapted to the LSB



Turbulence energy spectra

V=5m/s

Cold flow

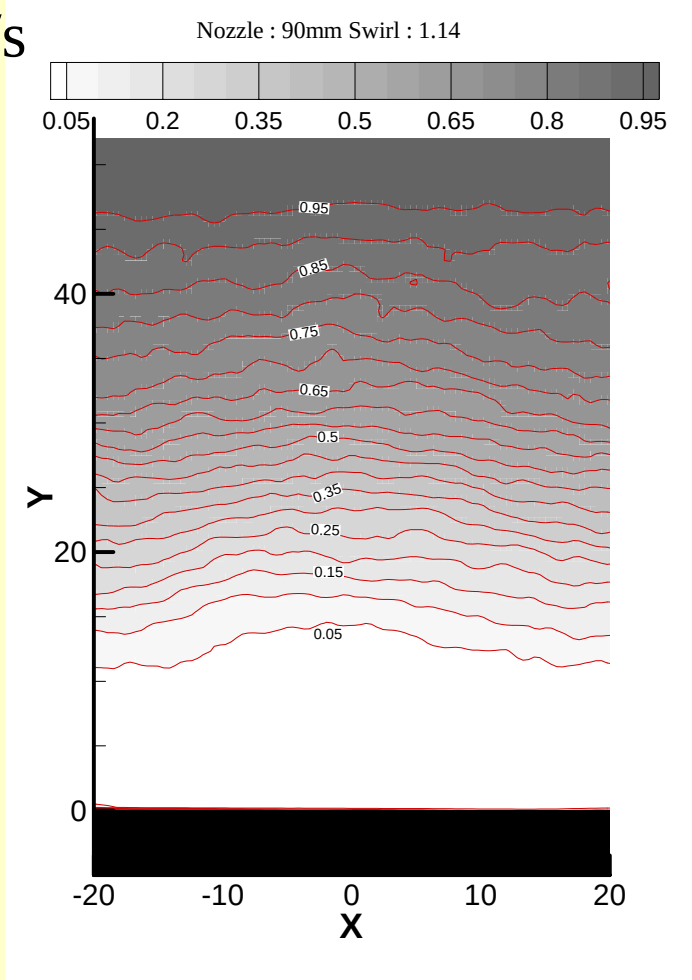


- Active grid operation produces higher energy than those of the passive grid
- Inertia range clearly appears in the case of active grid.

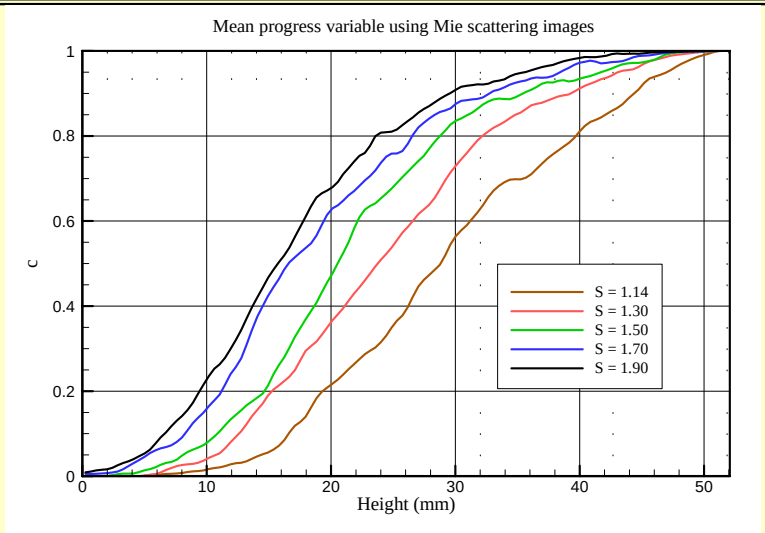
Mean progress variable distribution by PIV on reacting flow

V=5m/s

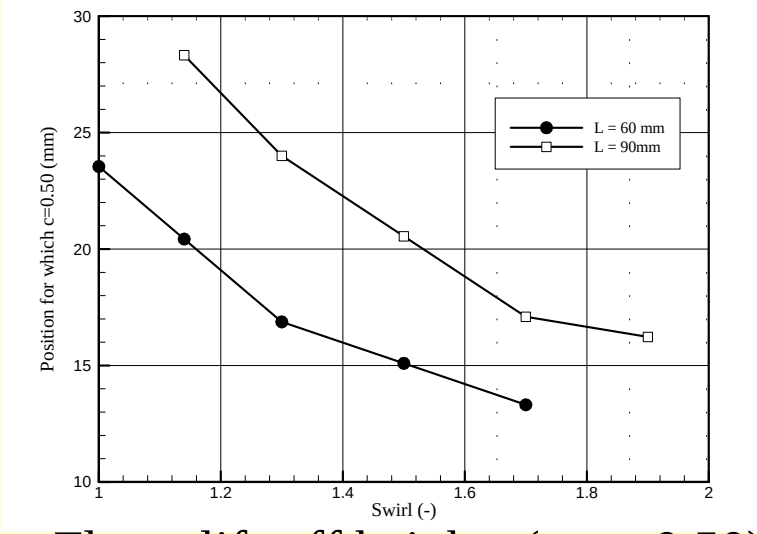
ϕ=0.70



Mean progress variable <c>

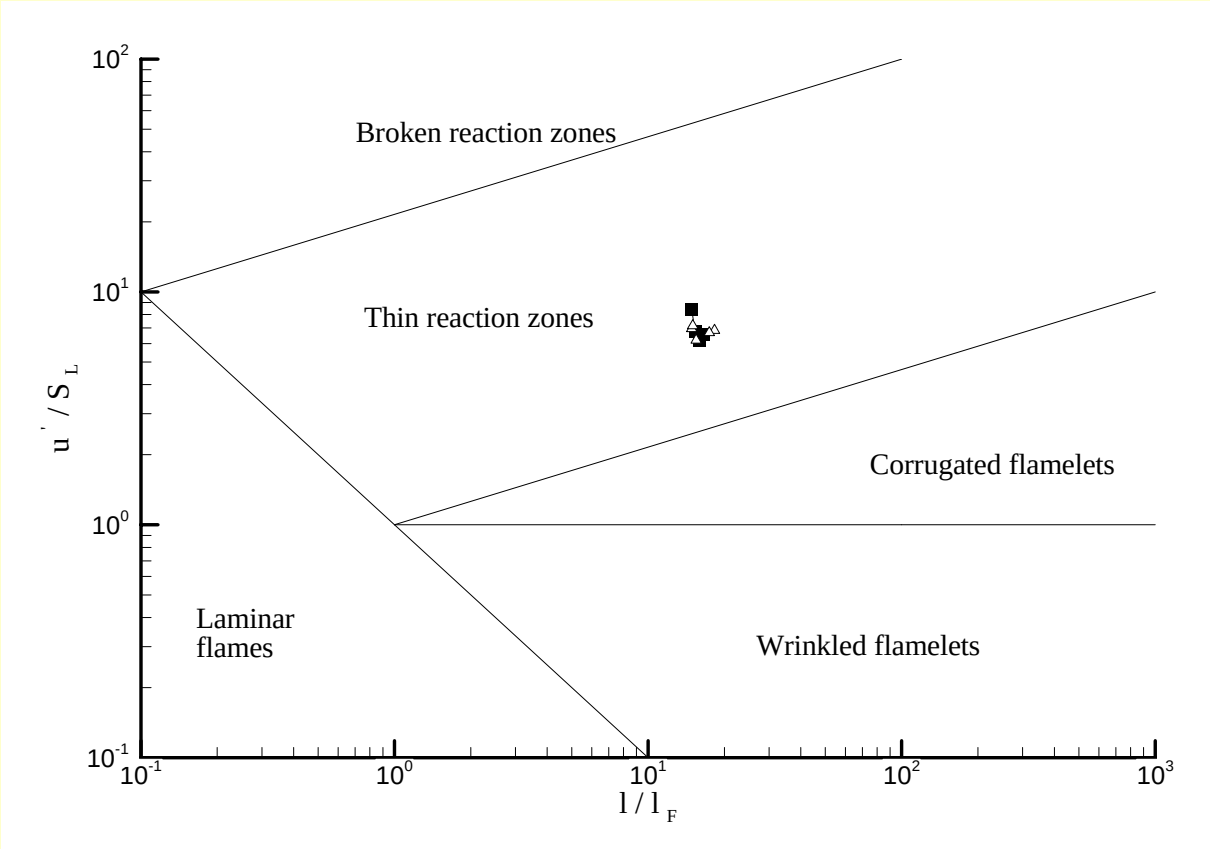


Distribution along the center line



Flame lift-off heights (<c>=0.50)

Regime plots



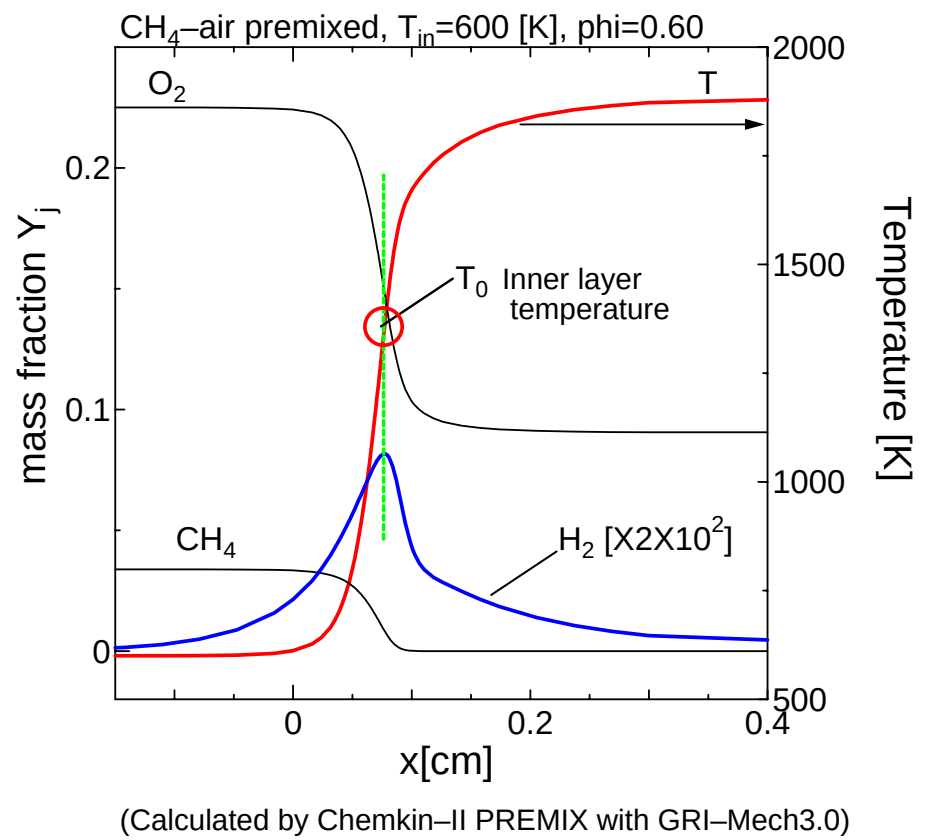
V=5m/s, S=1.0-1.9, ϕ=0.70, ω_{AG} :1000-2500pps and p_{AG} 200-1000 pulses.

Calculation of laminar flame thickness

$$\delta_F = \frac{(\lambda/c_p)_0}{(\rho s_L)_u}$$

N.Peters (2000) *Turbulent Combustion*

λ : Thermal conductivity
c_p : Specific heat
T_0 : Temperature at the inner layer



Chemkin-II, PREMIX (with GRI-Mech3.0) → $\lambda_0, c_{p0}, (\rho s_L)_u$

Integral scale

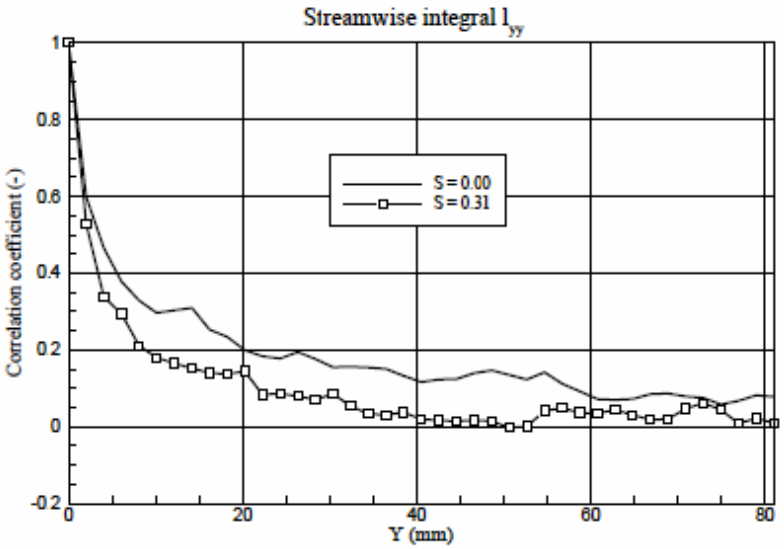


Fig. 1 Typical correlation for active grid

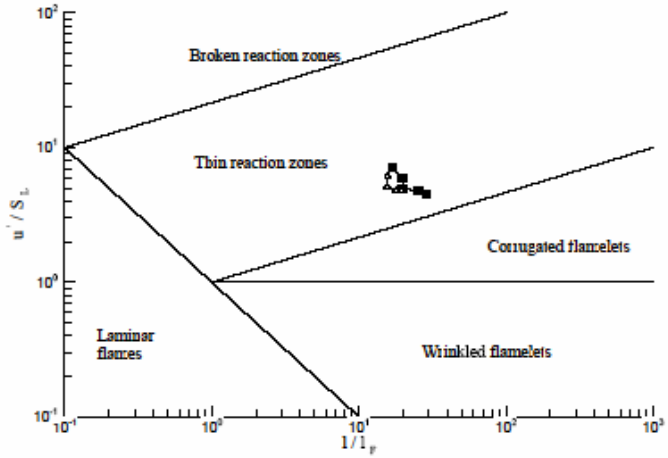
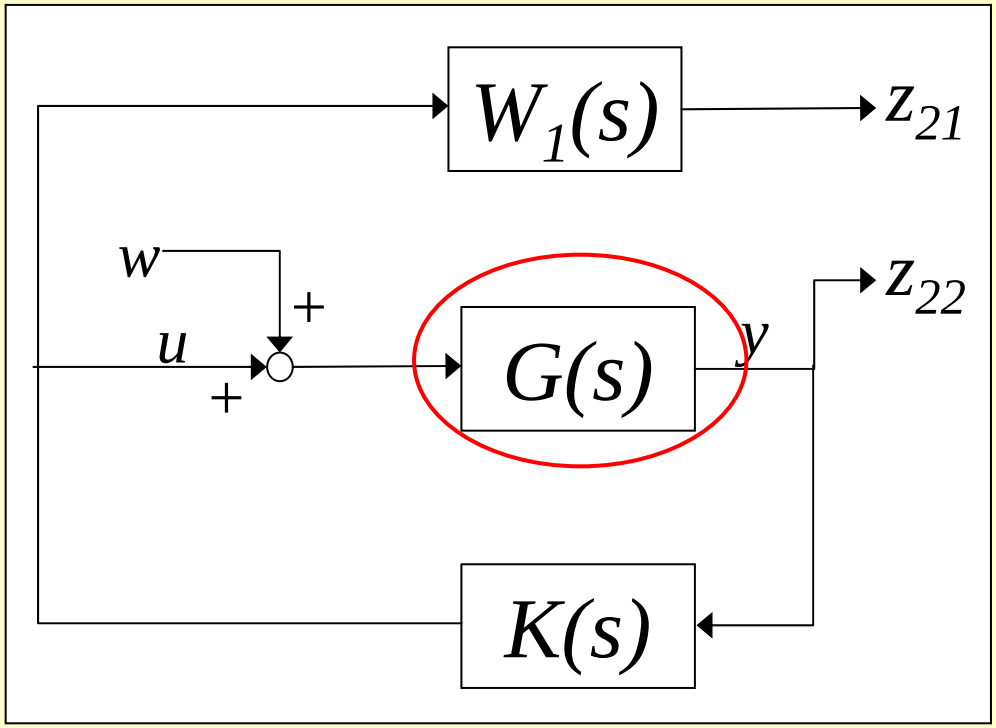
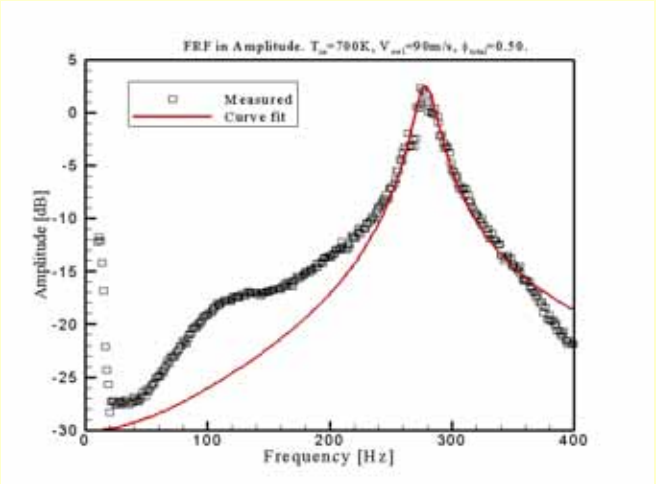


Fig. 22 Variation within the combustion diagram as function of PIV interrogation size

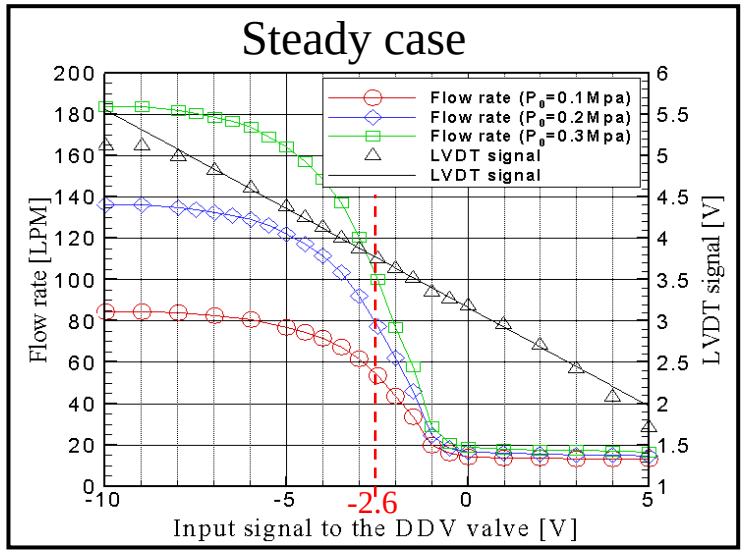
Flame response to actively modulated secondary swirl





Modulation of the swirl air flow rate by a high-speed valve

V_0=-2.6V, V_{p-p}=10V, Freq.=50Hz



Main mixture

DDV valve

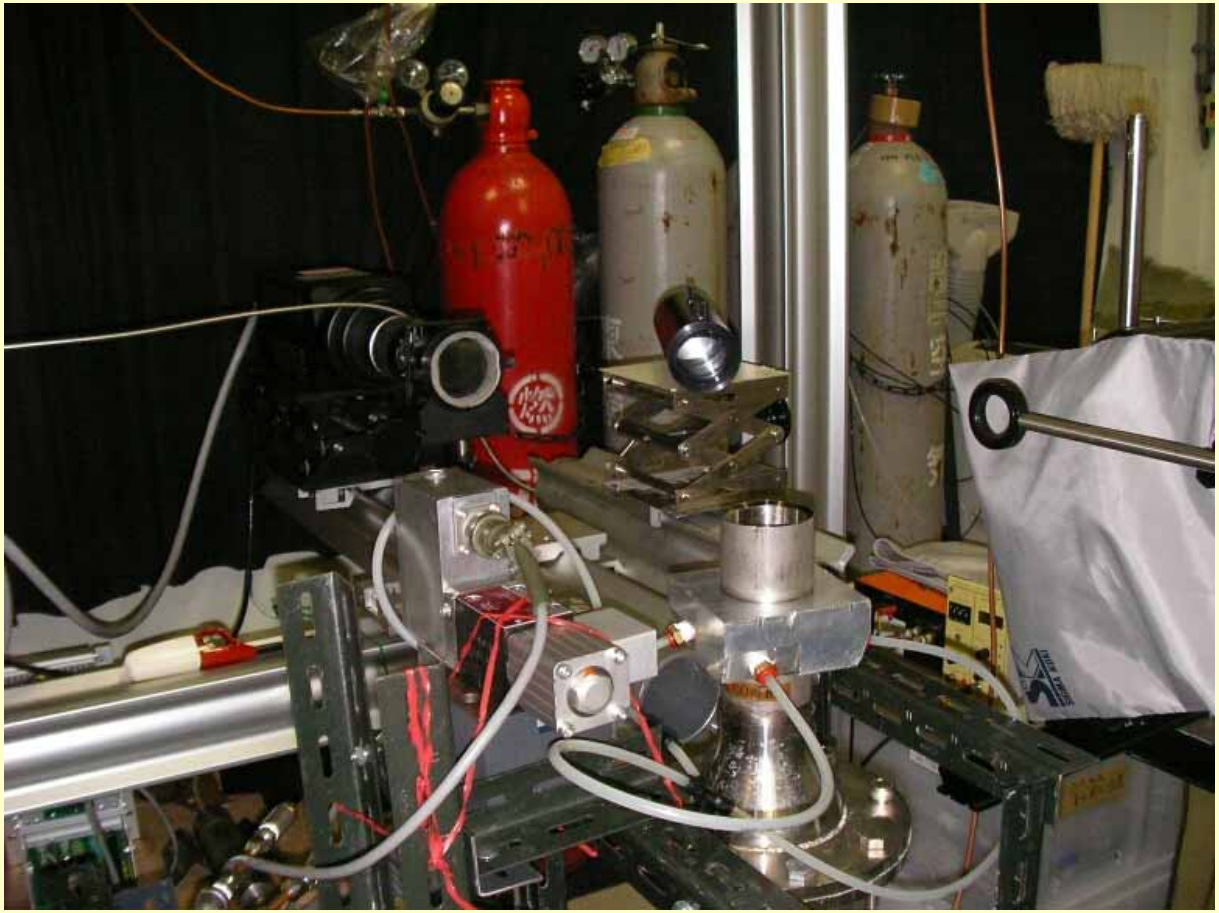
Plenum chamber

Secondary air

Valve controller

Signal generator

Measurement methods



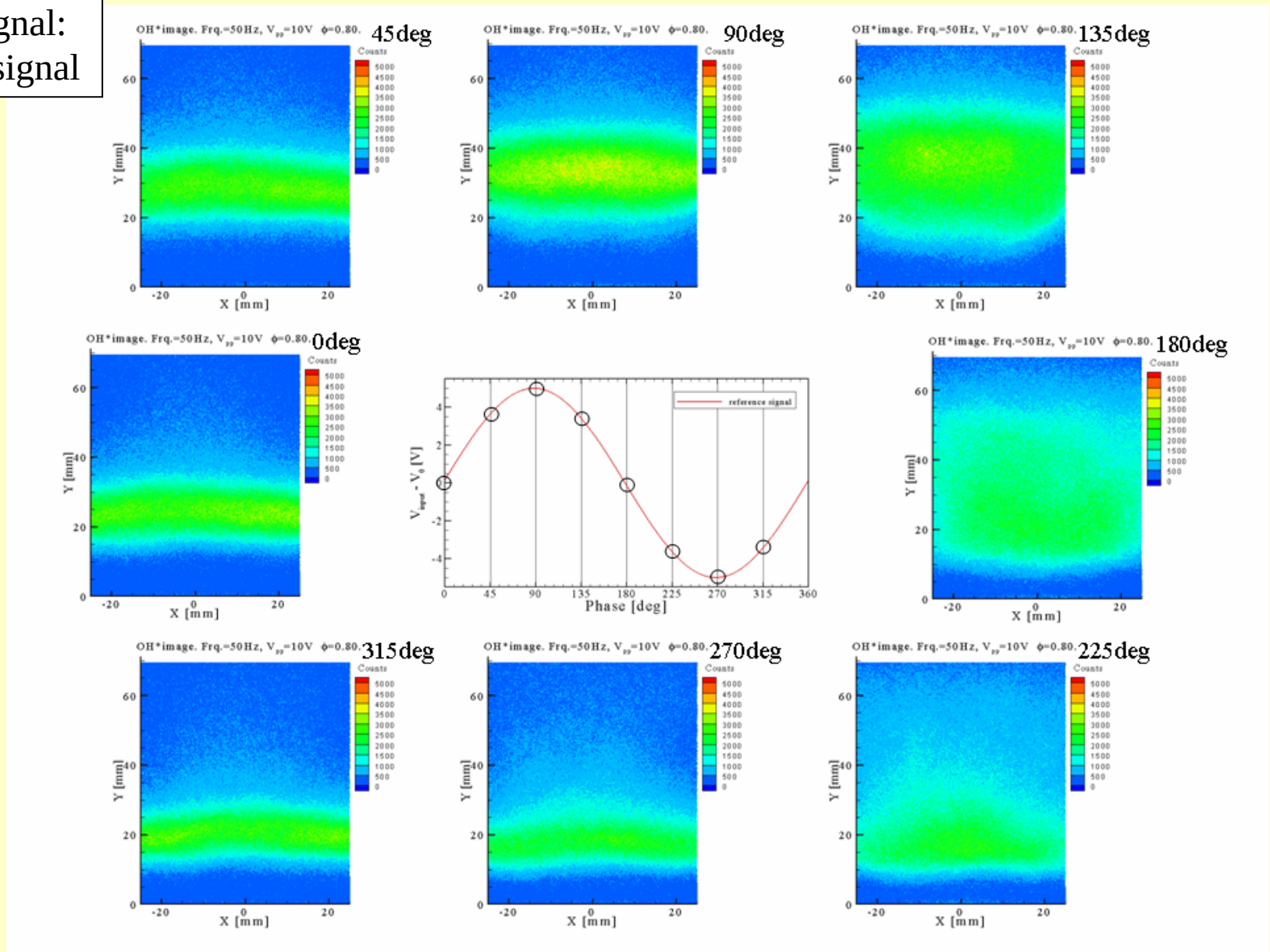
•OH* Chemiluminescence : PMT and ICCD (with a lens and optical filters)

•Velocity field: PIV (SiO_2 solid seeding particles)

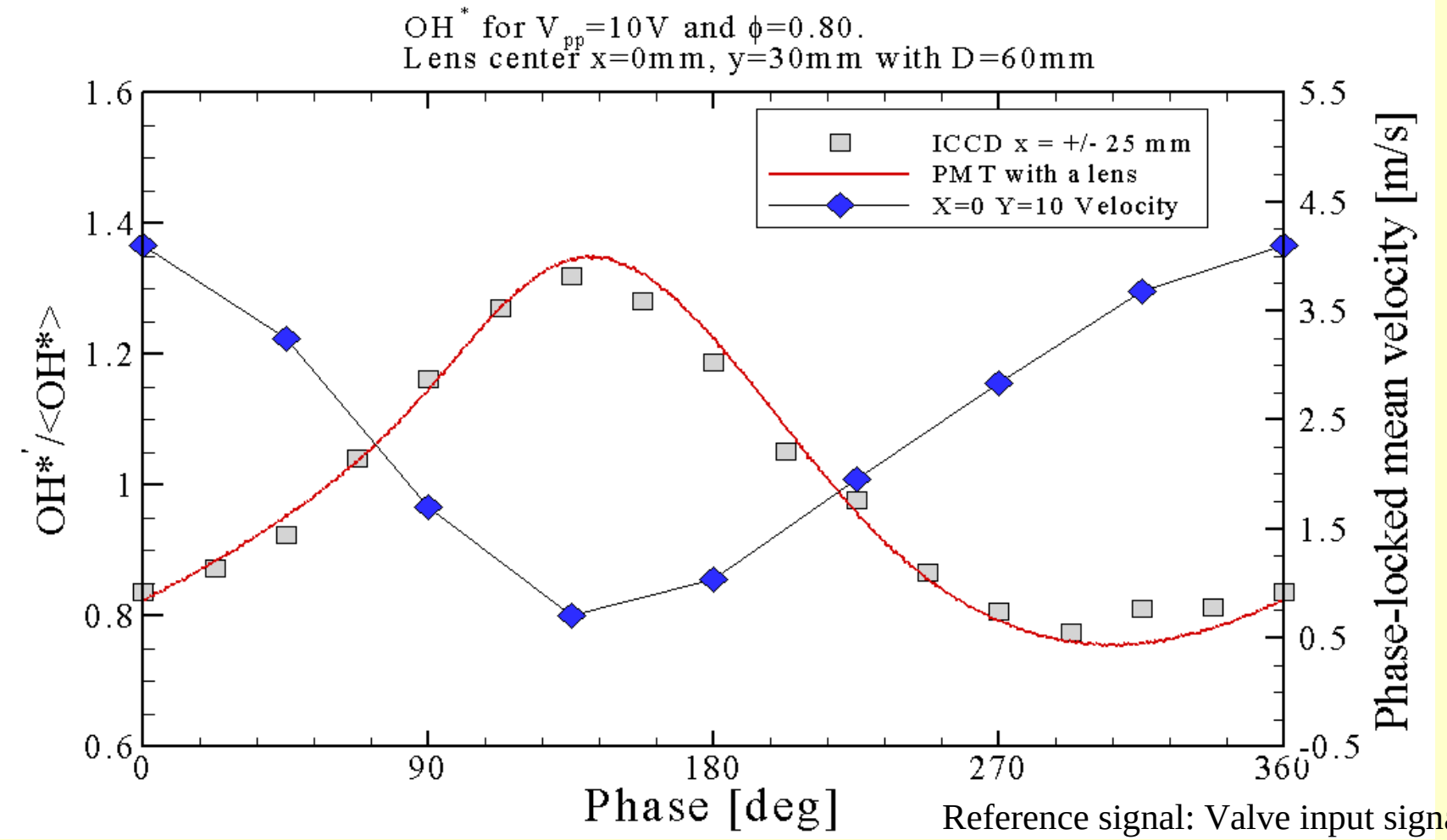
•Flame front detection: Mie scattering image for PIV

Phase-locked mean OH* image

Reference signal:
Valve input signal

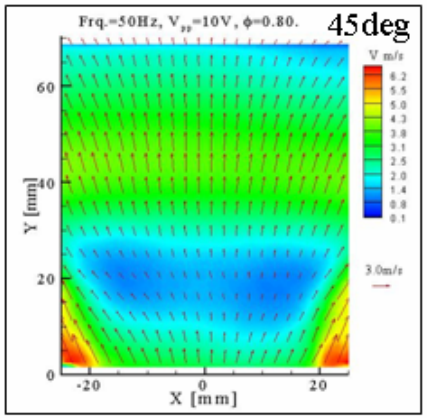


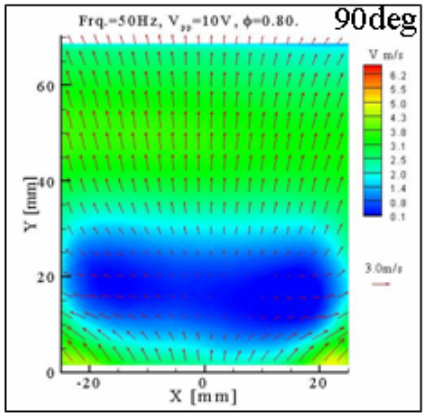
Phase-locked OH* from ICCD and PMT

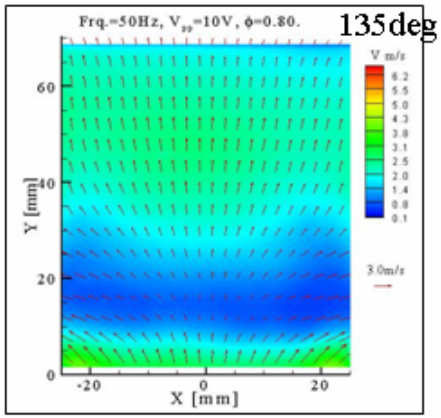


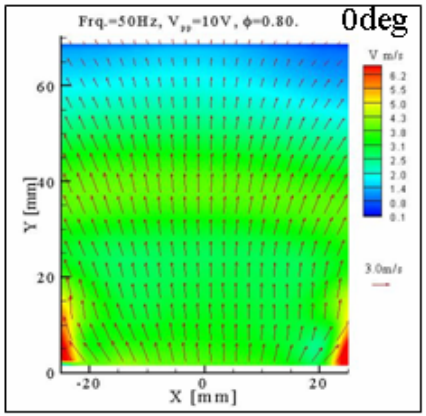
- The phase-locked OH*' signal from PMT shows good agreement with the data from ICCD.
- The PMT data can be used to see the flame response

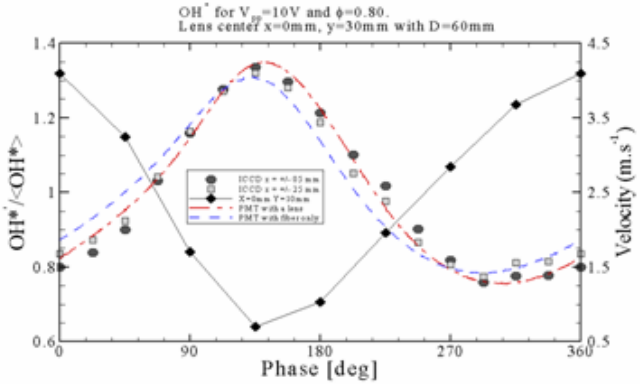
Phase-locked mean velocity field

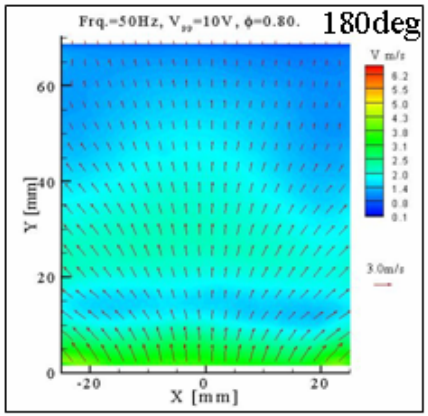


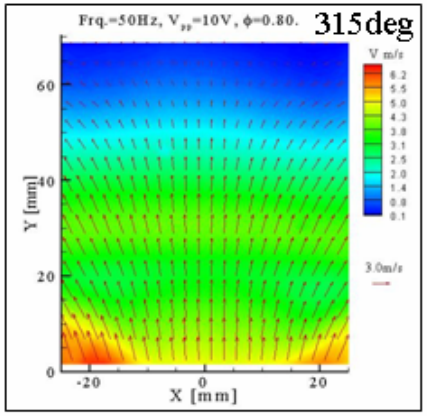


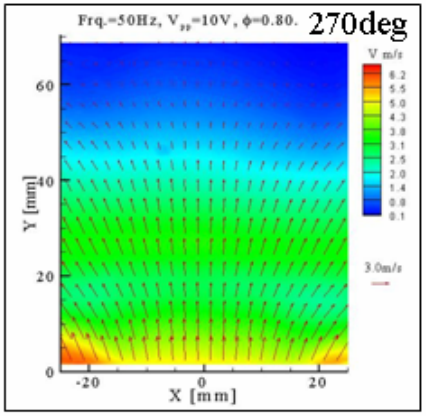


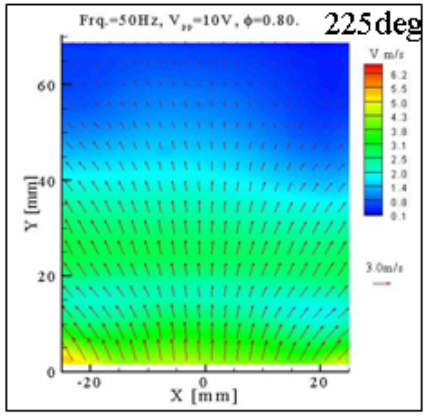




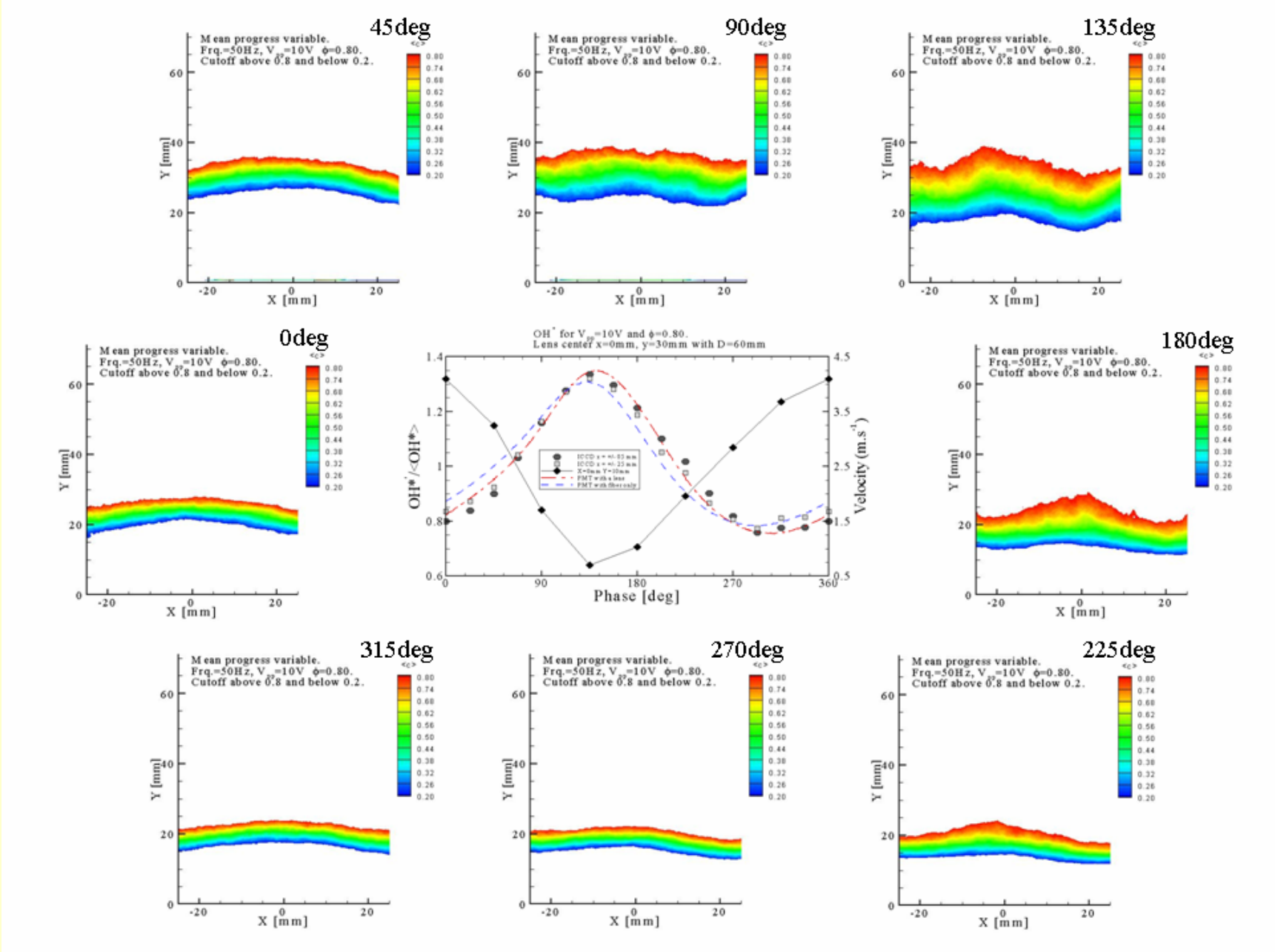




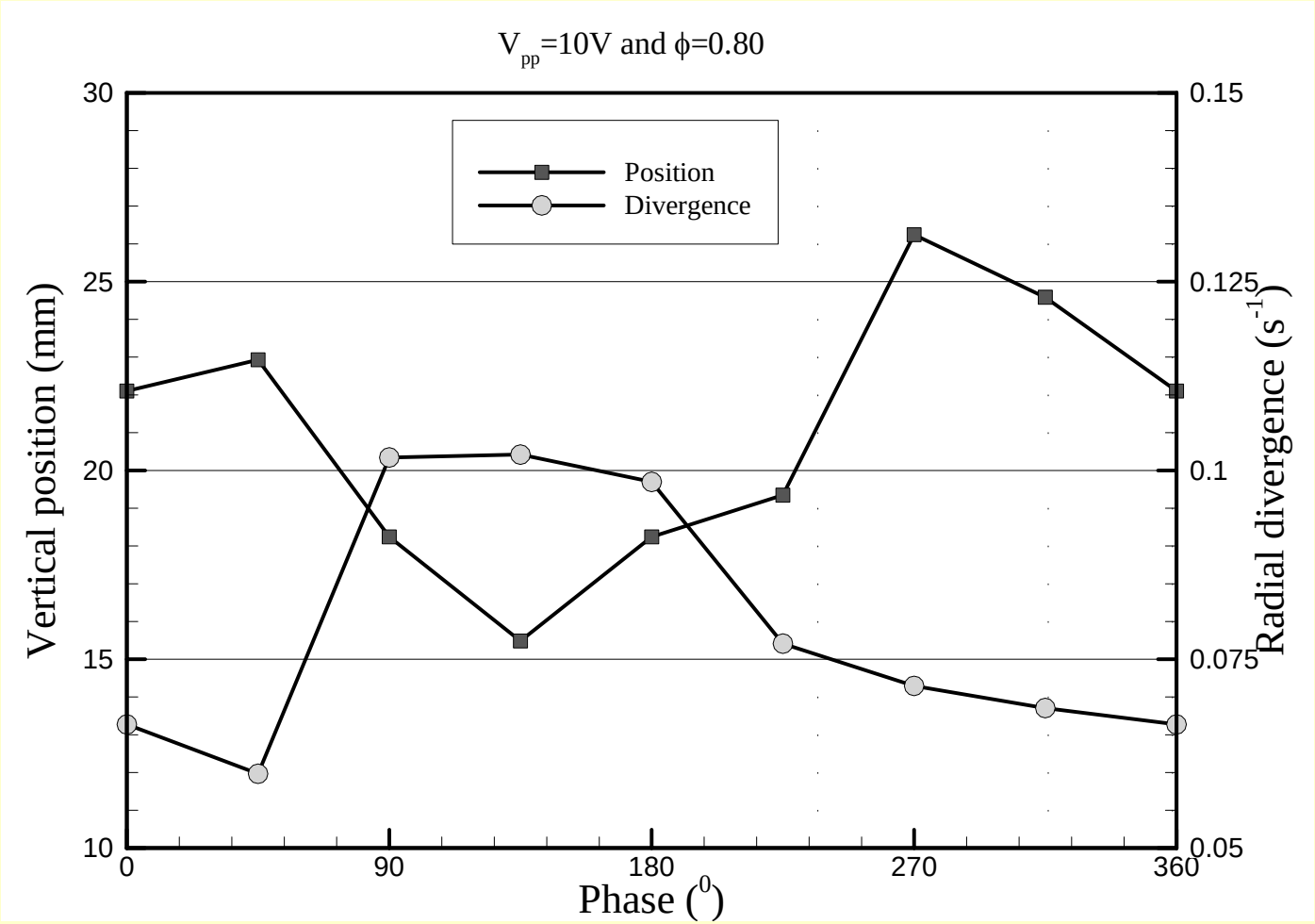




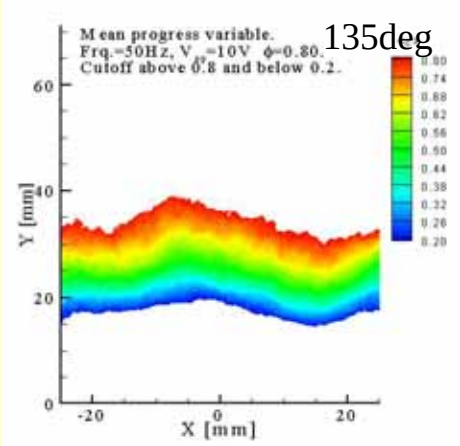
Phase-locked mean progress variable

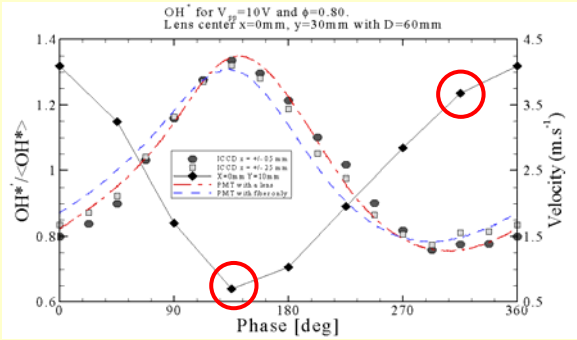


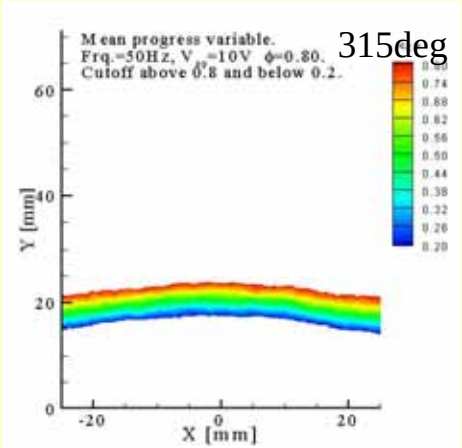
Divergent rate dU/dX

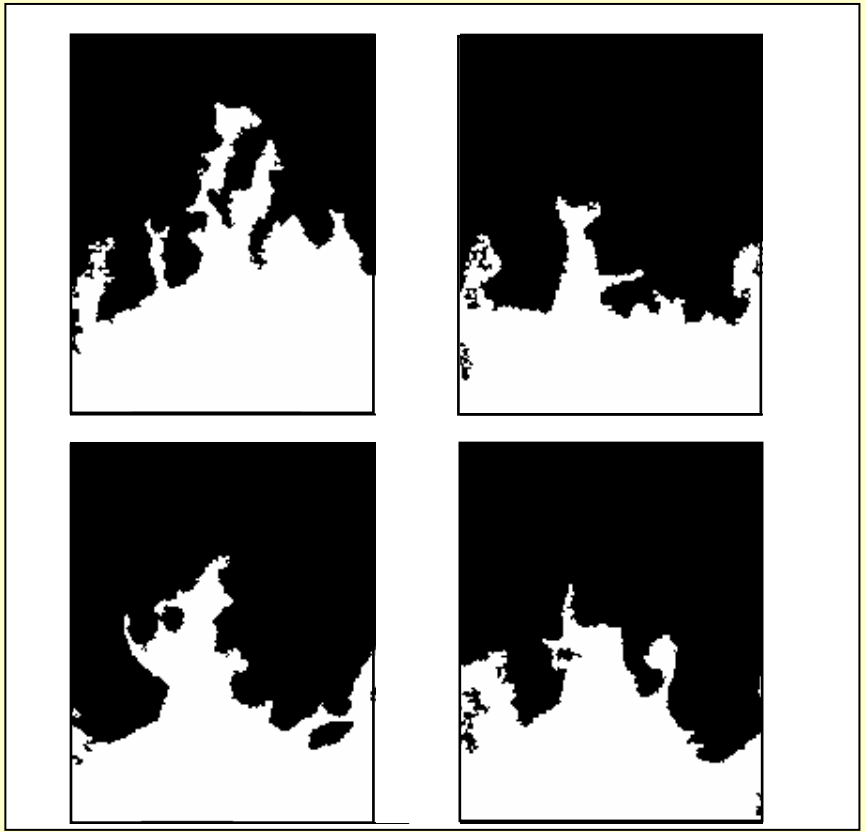


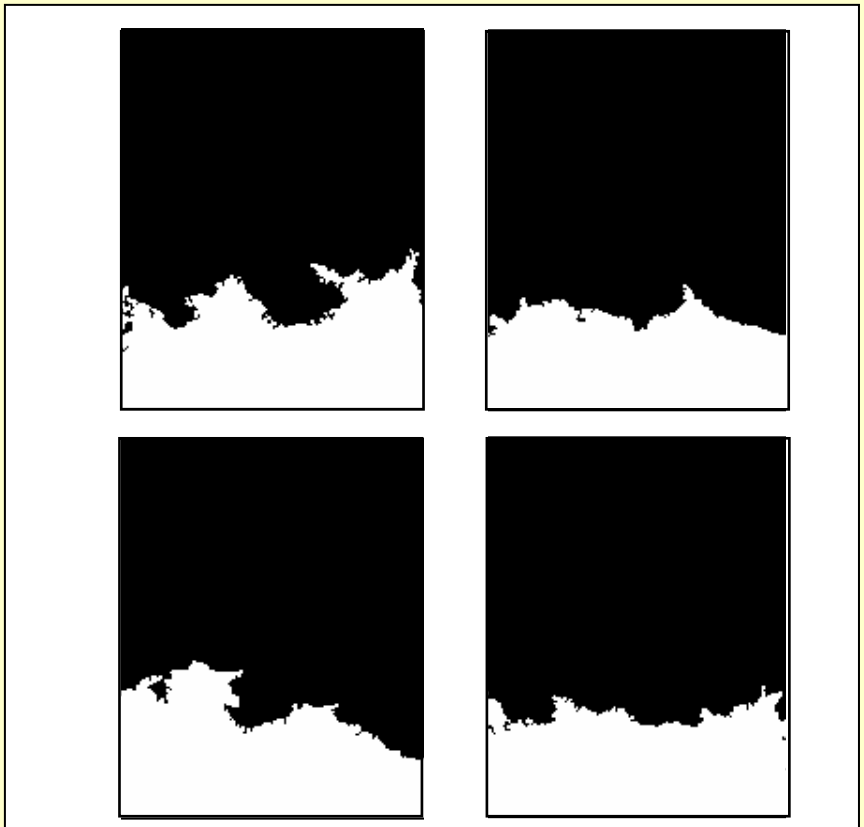
Instantaneous flame fronts



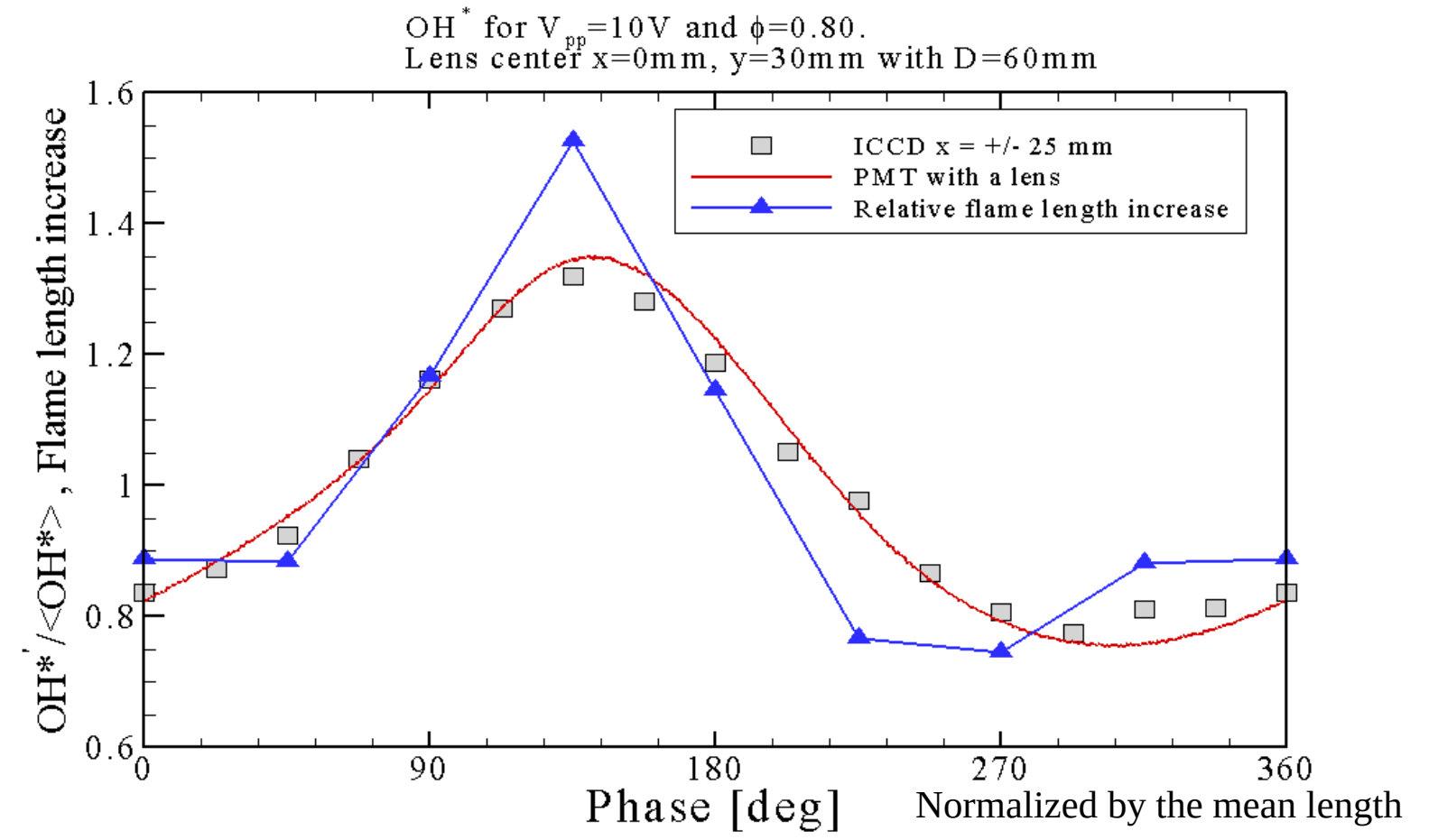








Flame length increase



- The flame length was calculated in the core region (-25<x<25mm)
- The effect from outer region should be taken into account

Summary

Active-Grid LSB (AG-LSB):

•Constant rotating period or rotating speed produced low-frequency spiky peaks in the energy spectra

•The low-frequency peaks diminished by applying a random operation of rotating period and speed

•Active grid operation made the inertia range broaden compare to the passive grid.

•The *u'* and integral scale were measured by PIV. The regime plots showed the produced flame is in the thin reaction zones regime.

Active-swirl LSB (AS-LSB):

•The results from 50Hz forcing was reported.

•OH* chemiluminescence intensity was measured by an ICCD and an PMT with optical filters. The phase-locked OH* profiles from the two methods showed good coincidence. The PMT data can be used to see the flame response.

•The phase-locked PIV measurements were conducted. The velocity fields and flame structure showed drastic change depending on the phase.

•The dynamic structure will be investigated further in detail.