Technical Specifications for
‘High speed PIV’ and ‘High speed PIV-PLIF’ system

MODULE A. HIGH SPEED PIV (3-C)

A1. Double Cavity High Speed Laser (up to 10 kHz):

The vendor should provide Dual Head (DH) laser that combines the output from two identical lasers in an external beam combination box, short temporal pulse separation, and/or alignment independence. In addition, the two laser beams can be triggered independently or simultaneously. The laser should satisfy the following specifications.

- Wavelength (nm): 527
- Pulse Energy (mJ) @ 1kHz : 2x40 (each head)
- Average Power (W): 90 (minimum)
- Pulse Width (ns) @ 1kHz: 150-200
- Repetition Rate: Single shot to 10 kHz
- Pulse to Pulse jitter:<0.5%
- Nominal beam Diameter ≤5.0 mm
- Beam Divergence:<10 mrad
- Beam Circularity:>85%
- Long Term Stability: 1% rms
- Interface: RS 232, External TTL Triggering, GUI software included
- Operating Voltage: 100 - 240 V
- Line Frequency: 50-60 Hz
- Preferred length of chord between power supply and head unit: ≥3 m
- Built in beam combining optics
- Internal and external trigger option
- Flexibility in time delay between pulse pairs
- Warranty (minimum 36 months from the date of commissioning)
- AMC for additional 24 months
- On-site training should be provided

A2. High speed optical components

A2.1. Single compact light sheet optics unit

- Should generate parallel and divergent light sheet.
- Suitable for high speed PIV measurement with coatings for loss less than 5%.
- Adjustable focus: minimum 0.3 m to 3 m.
- Adjustable light sheet thickness and light sheet angle
● 360 degrees adjustable light sheet orientation
● Mountable on articulated mirror arm or can be used as separate unit
● Adapter piece for mirror arm
● Output lens units for fixing multiple light sheet angles

A2.2 Articulated arm

● Light guiding arm to connect laser head to light sheet optic
● Aperture: minimum of 10 mm
● Length: ≥1.8 m
● Optimum mirror combination with antireflection coating for 532 nm
● Mirrors capable of withstanding energy produced from a high speed laser head.
● Mounting block
● High mechanical stability
● Safe laserbeam guidance between laser and experiment
● 360° orientation and positioning of light sheet
● Automatic traversing
● Rugged case for transport and storage

A3.1 High speed camera (2 in numbers)

● Minimum Resolution of 1 MP
● Frame speed ≥5000 fps @ the above prescribed resolution
● Sensor 12-bit CMOS with a sensor size between 10μm to 20 μm.
● Minimum onboard memory 32GB
● Global electronic shutter≤1 μs independent of frame rate
● Capable of working in low light conditions with ISO of ≥6400(daylight)
● Phase locking option to synchronize camera with an external source
● Image Formats JPEG, AVI, TIFF, BMP, RAW (compressed or uncompressed), PNG and FTIF.
● Active cooling unit to cool the camera
● Operating Temperature 20-40 °C
● Power requirements 100 V - 240 V AC ~ 1.5 A, 50-60 Hz
● All necessary cables should be provided including BNC cable for triggering purposes
● Rugged camera case
● Adapter (F, C, EOS and EF) to mount the appropriate lens

A3.2 Camera Lens (2 in numbers)

● Macro lens for Camera with minimum 50 mm focal length
● Aperture f/1.4

A3.3 Band pass filter

● Wavelength 527±nm
● FWHM±10 nm
● Transmissivity>80% @ 527 nm
A4. **Synchronizer**

For synchronisation of high speed PIV components

- Minimum of 8 outputs and 2 input channels for triggering
- Ethernet (TCP/IP) control with the suitable software
- Time resolution maximum of 1 ns
- Jitter ≤ ±0.2 ns
- 5ns rise time, TTL compatible pulse
- Repetition rates from 0.1 Hz up to 10 MHz
- Delay between external triggers (minimum 30 MHz)
- 100 Mb ethernet connection for communication with PC
- Laser power control by Q-Switch delay
- Positive or inverted TTL signal for all outputs configurable
- Software for standard and high speed PIV timing

A5. **3-D Tilt adapter** or **Tilt-shift lens (2 in number)**

Required for stereo-PIV (3-C measurement).

A6. **Seed generator and particles**

- Seeding particle generator for gas-phase with droplet diameter of ≤2 microns and compatible liquid.
- Seeding-particles with diameter ≤50 microns for liquid phase phase velocity measurement

A7. **Calibration grid compatible with 3C PIV measurement**
MODULE B. High speed PIV-PLIF facility

B1. Laser for high speed PIV

Double cavity high speed laser:

The vendor should provide Dual Head (DH) laser that combines the output from two identical lasers in an external beam combination box, short temporal pulse separation, and/or alignment independence. In addition, the two lasers can be triggered independently or simultaneously.

- Wavelength (nm): 527
- Pulse Energy (mJ) @ 1kHz: 2x40 (each head)
- Average Power (W): 90 (minimum)
- Pulse Width (ns) @ 1kHz: 150-200
- Repetition Rate: 100 Hz to 10 kHz
- Pulse to Pulse jitter: <0.5%
- Nominal beam Diameter: ≤5.0 mm
- Beam Divergence: <10 mrad
- Beam Circularity: >85%
- Long Term Stability: 1% rms
- Interface: RS 232, External TTL Triggering, GUI software included
- Operating Voltage: 100 - 240 V
- Line Frequency: 50-60 Hz
- Preferred length of chord between power supply and head unit: ≥3 m
- Built in beam combining optics
- Internal and external trigger option
- Flexibility in time delay between pulse pairs
- Warranty (minimum 36 months from the date of commissioning)
- AMC for additional 24 months
- After successful installation **On-site training** for 7 days should be provided

B2 Laser for high speed PLIF

B2.1 Pump Laser

- Diode pumped, frequency doubled Laser
- Wavelength: 532 nm
- Pulse repetition rate: 0.1 Hz to 10 kHz
- Pulse energy @ 10 kHz: 4 mJ
- Maximum average power: 50W (minimum)
- Pulse length: ≤10ns
- Beam quality: M² < 3
- Beam diameter: ≤5mm
- Beam profile: Gaussian/Top-hat
- Energy stability (rms): < 4%
- Power supply along with chiller for smooth laser operation
- Warranty (minimum 36 months from the date of commissioning)
- AMC for additional 24 months
- After successful installation **On-site training** for 7 days should be provided

**B2.2 Dye Laser**

- Wavelength: 532 nm
- Frequency doubling unit
- Output energy (mJ) @ 10 kHz: ≥0.1 mJ
- Tuning range with frequency doubling unit: 220nm - 320 nm
- Polarization should be >98% (vertical)
- Software control of laser
- Warranty (minimum 36 months from the date of commissioning)
- AMC for additional 24 months
- After successful installation **On-site training** for 7 days should be provided

**B3. Optical components**

**B3.1. Light sheet optic (single compact unit):**

- Should generate parallel and divergent light sheet.
- Suitable for high speed PIV measurement with coatings for loss less than 5%.
- Adjustable focus: minimum 0.3 m to 3 m.
- Adjustable light sheet thickness and light sheet angle
- 360 degrees adjustable light sheet orientation
- Mountable on articulated mirror arm or can be used as separate unit
- Adapter piece for mirror arm
- Output lens units for fixing multiple light sheet angles

**B3.2. Band pass filter**

- Wavelength 527±nm
- FWHM ±10 nm
- Transmissivity >90% @ 527 nm

**B3.3. OH-LIF Filter:**

  optical Filter for OH LIF 270-325nm, transmission up to 80%.

**B3.4. Divergent Light Sheet Optic - UV Version**

- Should generate parallel and divergent light sheet.
- Suitable for high speed PLIF measurement with coatings for loss less than 5%.
- Adjustable focus: minimum 0.3 m to 3 m.
- Adjustable light sheet thickness and light sheet angle
- 360 degrees adjustable light sheet orientation
- Mountable on articulated mirror arm or can be used as separate unit
- Adapter piece for mirror arm
- Output lens units for fixing multiple light sheet angles

B4.4. **Beam combining optics for PIV & PLIF (Dichroic optic)**

B4.1 **High speed camera (2 in numbers):**

- Minimum Resolution of 1 MP
- Frame speed ≥5000 fps @ the above prescribed resolution
- Sensor 12-bit CMOS with a sensor size between 10μm to 20 μm.
- Minimum onboard memory 32GB
- Global electronic shutter ≤ 1 μs independent of frame rate
- Capable of working in low light conditions with ISO of ≥6400 (daylight)
- Phase locking option to synchronize camera with an external source
- Image Formats JPEG, AVI, TIFF, BMP, RAW (compressed or uncompressed), PNG and FTIF.
- Active cooling unit to cool the camera
- Operating Temperature 20-40 °C
- Power requirements 100 V - 240 V AC ~ 1.5 A, 50-60 Hz
- All necessary cables should be provided including BNC cable for triggering purposes
- Rugged camera case
- Adapter (F, C, EOS and EF) to mount the appropriate lens
- Warranty (minimum 36 months from the date of commissioning)
- AMC for additional 24 months
- On-site training should be provided

B4.2. **Camera Lens**

- Macro lens for Camera with minimum 50 mm, f/1.4

B4.3. **UV-lens for PLIF camera**

- UV-Lens for camera
- focal length = 100mm
- Free Aperture: 50mm
- Focal depth f/2
- Corrected for a wavelength between 200 nm to 450nm

B5. **Synchronizer**

- Should be able to work in high speed mode
- Minimum of 8 outputs and 2 input channels for triggering
- Ethernet (TCP/IP) control with the suitable software
- Time resolution maximum of 1 ns
- Jitter \( \leq \pm 0.2 \) ns
- 5 ns rise time, TTL compatible pulse
- Repetition rates from 0.1 Hz up to 10 MHz
- Delay between external triggers (minimum 30 MHz)
- 100 Mb ethernet connection for communication with PC
- Laser power control by Q-Switch delay
- Positive or inverted TTL signal for all outputs configurable
- Software for standard and high speed PIV timing

**B6. Synchronizer for PLIF module**

- Should be able to work in high speed mode
- Minimum of 8 outputs and 2 input channels for triggering
- Ethernet (TCP/IP) control with the suitable software
- Time resolution maximum of 1 ns
- Jitter \( \leq \pm 0.2 \) ns
- 5 ns rise time, TTL compatible pulse
- Repetition rates from 0.1 Hz up to 10 MHz
- Delay between external triggers (minimum 30 MHz)
- 100 Mb ethernet connection for communication with PC
- Laser power control by Q-Switch delay
- Positive or inverted TTL signal for all outputs configurable
- Software for standard and high speed PIV timing

**B7. Image intensifier**

- For use in combination with Hi-Speed camera operating up to 100000 fps
- Output diameter: 25mm (to match with the larger high-speed image sensors)
- Standard C-mount and F-mount input and output.
- Spectral range: 190 - 800 nm.
- Maximum repetition rate: 100-300 kHz
- Minimum gating: 10 ns
- Optimized 1:1 lens coupling
- Optics compatible for use with high speed camera
- Warranty (minimum 36 months from the date of commissioning)
- AMC for additional 24 months
- On-site training should be provided

**B8. Mounting table for dye laser:**

- Optical table for mounting both pump and dye laser (compatible with the lasers)
B9. 3-D Tilt adapter or Tilt-shift lens (2 in number)

B10. Calibration grid for 3C PIV

B11. Compatible Seeding particle generator for PIV

- Seeding particle generator for gas-phase with droplet diameter of ≤2 microns and compatible liquid (for ambient condition tests)
- Seeding particles for gas phase should be Zirconium oxide or Titanium dioxide (for high temperature studies) along with a compatible generator
- Seeder particles for with diameter ≤50 microns for liquid phase flows

B12. Power meter to measure laser power (1 qty)

Module C: Common requirements for Module A and Module B

C1. Softwares

C1.1 PIV Software (2 in numbers)

- For 2D-3C PIV processing
- 2 User license allowing usage of the user interface
- Minimum - 8 batch licenses allowing parallel processing on 8 processors
- Image pre-processing and post processing features
- Cross-correlation, autocorrelation and speckle-shift analysis modes
- Supports TIFF, BMP, JPEG, PNG, and other image formats
- Image batch processing
- Vorticity, velocity calculation for each image frame
- Time averaged statistics like rms of velocity fluctuations for turbulent flows
- Output data should be compatible with the plotter like Matlab, Tecplot

C1.2 Software for LIF:

- 1 User license allowing usage of the user interface
- Minimum - 8 batch licenses allowing parallel processing on 8 processors
- Automated recording and mapping of images for background and sheet correction, (considering non-uniform light sheet illumination) and calibration image
- Conversion of camera signals to concentration according to a measured calibration function
- Supports TIFF, BMP, JPEG, PNG, and other image formats
- Image batch processing
- Software should enable the user to use individual images.
- The individual images should be in a format which can be accessed by a third party software (e.g. MATLAB etc.)
C1.3 Software to control camera and synchronizer from PC

C2. Workstations (2 in numbers): Workstations should have the following minimum specifications or higher
- Intel Server Motherboard
- Intel Xeon processor with base frequency 2.8 GHz or higher
- 128GB DDR3 2400 Mhz for Server
- Seagate Hard Disk 2 TB (SATA)
- Additional slots should be available for future expansion of HDD
- Kingston 256 GB SSD
- NVIDIA GT610(2GB) – ZOTAC
- Display (23” LED), keyboard and mouse, optical drive
- Power supply

C3. Long distance microscope for PIV application
- Focus Range: At least 60 cm to 150 cm
- Optical Resolution: At least 2.7 microns of higher

C4. Laser safety goggles for for PIV Laser (4 in number)

C5. Laser safety goggles for PLIF laser (4 in number)

Terms and conditions:

1. All the components should have above mentioned minimum specifications. If there are specific items (related to particular supplier), which is required beyond the above mentioned list for successful performance of the facility, then those should be mentioned and provided.
2. Vendors should mention cost of each of the components separately.
3. After successful installation of the facility 7 days user training for at least 10 users are mandatory.
4. Minimum warranty period for all the components (unless mentioned separately) are 2 years. Warranty includes replacement of the damaged parts and onsite visiting charge.