1. INTRODUCTION

Nucleate boiling is important in many energy systems including light water reactors. Currently significant efforts are underway to develop mechanistic models for nucleate boiling based on computational fluid dynamics (CFD) [1-3]. Development and validation of these models require new high fidelity experimental data with high spatial and temporal resolutions. Previous work such as [4] has measured temperature distributions and diameter of a growing bubble. It is important to obtain further information, such as bubble shape during growth and after departure, and velocity profiles in the liquid. This paper presents an improved experimental approach for synchronized measurement of these data.

2. EXPERIMENTAL SETUP

Fig. 1 shows a schematic of the experimental facility. Nucleate pool boiling is achieved in a boiling cell with an isothermal bath, the temperature of which is regulated by circulating a temperature controlled liquid from a heater unit. Bubbles are generated on the surface of a specially designed indium-tin-oxide (ITO) heater. An advanced Particle Imaging Velocimetry (PIV) system, including high speed video (HSV), and Infrared Thermometry (IR) are synchronized to achieve the measurements mentioned above. Table I summarizes the measurement capabilities of the facility.

![Fig. 1. Schematic of the pool boiling facility.](image)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Bubble dimensions (HSV)</th>
<th>Surface temperature (IR)</th>
<th>Liquid velocity (PIV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>0.1 mm - 12 mm</td>
<td>50-150°C</td>
<td>6 mm/s - 0.32 m/s</td>
</tr>
<tr>
<td>Spatial resolution</td>
<td>20µm</td>
<td>0.1 mm</td>
<td>0.64 mm</td>
</tr>
<tr>
<td>Temporal resolution</td>
<td>0.2 ms - 1 ms</td>
<td>0.34 ms - 1 ms</td>
<td>0.5 ms - 1 ms</td>
</tr>
<tr>
<td>Accuracy</td>
<td>60 μm</td>
<td>2°C</td>
<td>2% of measured value</td>
</tr>
</tbody>
</table>

3. RESULTS AND DISCUSSION

Synchronization of the devices is achieved through the high speed controller. Fig. 2 shows the synchronized HSV images and IR images of (a) boiling visualized from underneath a heater and (b) HSV images from the side and
IR images viewed from underneath the heater, both at 1000Hz. Fig. 3(a) shows a picture of the PIV results of a departed bubble (t=25ms after nucleation). PIV gives the details of the bubble shape and water velocity around the bubbles. Fig. 3(b) shows an example of the heater surface temperature under a growing bubble. The blue (darker in print) ring indicates the micro-layer region, where heat transfer is most intense. Detailed temperature variation with time can be obtained; the solid curves indicate temperature decreasing with time and dashed curves indicate temperature regain with time before bubble departure. Time zero is when the nucleation starts.

Fig. 2. (a) Synchronized HSV (left images) and IR (right images) for two frames 1ms apart, viewed underneath the heater. (b) Synchronized HSV images (top) viewed from the side and IR images(bottom) viewed underneath the heater.

Fig. 3. (a) Velocity profile from a growing and departed bubble. (b) Radial surface temperature under a growing bubble.

4. CONCLUSIONS
This paper presented a new experimental approach for investigation of nucleate pool boiling phenomena. With synchronized high-speed video, PIV and IR thermometry, this facility is capable of simultaneous non-intrusive, time- and space-resolved measurement of key nucleate boiling parameters, including bubble departure diameter and frequency, and velocity and temperature fields around and beneath the bubble. This data can be used to gain insight into the fundamentals of nucleate boiling, and to validate mechanistic models of nucleate boiling.

5. REFERENCES