OSU's Cyber-enabled Combined Raman-FTIR Microprobe

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Purpose of the Document:

This document describes the project outcomes of the partnership between the Ohio Supercomputer Center and The Ohio State University to cyber-enable the Combined Raman-FTIR Microprobe spectrometer at OSU's Analytical Spectroscopy Laboratory, Department of Chemistry.

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Executive Summary

The Ohio State University's Combined Raman-FTIR Microprobe instrument (Raman-FTIR) shown in Figure 1 is an expensive and rare scientific instrument used to get complimentary Raman-IR information about chemicals. It was acquired recently through a NSF CRIF: MU Program grant. Cyber-enabling the Raman-FTIR instrument resources and related data sets using remote instrumentation solutions can improve user convenience, avoid duplication of instrument investments and significantly reduce costs.

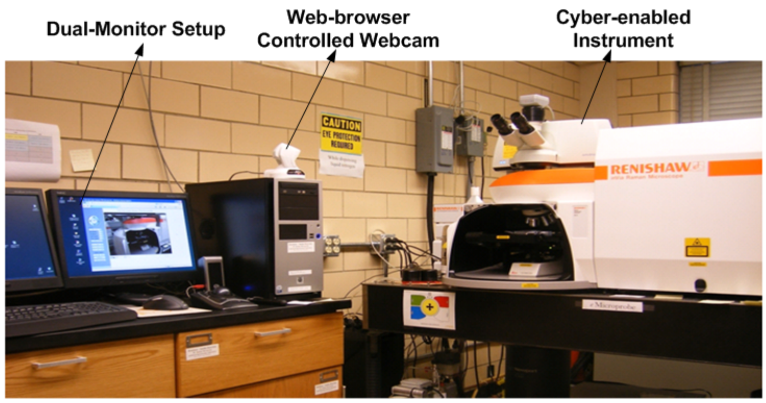

Figure 1: OSU's Cyber-enabled Raman-FTIR Microprobe Instrument

Ohio has long had a collaborative group of institutions which have worked together, using Ohio Board of Regents funds, to make sure that Ohio leads other states in the quality of its instrument facilities. In this project, the Ohio Supercomputer Center (OSC) partnered with OSU to cyber-enable the Raman-FTIR by developing a remote instrumentation software that leverage OSC's software development and networking resources for research and training. Specifically, OSC developed and deployed the "Remote Instrumentation Collaboration Environment (RICE)" software that provides remote observation and remote operation capabilities to multiple simultaneous users of the Raman-FTIR. RICE features include: (a) Collaboration tools (VoIP, chat, presence, control-lock passing) to orchestrate instrument control amongst multiple remote users, (b) Remote-site dual-desktop resolution, and (c) Network health monitoring coupled with network performance anomaly detection using a "plateau-detector algorithm" that warns and blocks user's control-actions during impending and extreme network congestion periods. The RICE solution for the Raman-FTIR has been developed with careful considerations to: instrument safety, network and data security, open-standards without licensing restrictions, extensibility to other instruments, and ease of on-going maintenance. With the help of lab and IT infrastructure personnel at OSU, the RICE software has been successfully deployed by OSC, and made available to local students and researchers to work from comfort of their offices or homes, and for remote access of OSU's collaborators: California State University, Dominguez Hills, CA; Oakwood University, Huntsville, AL.

The capabilities of the cyber-enabled Raman-FTIR have been demonstrated at the NSF Cyber-enabled Instrumentation Workshop, Internet2 Fall Member Meeting, and ACM/IEEE Supercomputing Conference. Such demonstrations are intended to make available the Raman-FTIR resources and instructional materials to remote user communities who do not have access to Raman-FTIR technologies and related instructional materials to engage students. Further, they are intended to encourage wider-adoption of the OSC-developed solutions amongst the Ohio's universities and their national and international partners.

1 Remote Instrumentation Requirements

The user scenarios supported by the OSC developed solutions for research and training of the Cyber-enabled Raman-FTIR are as follows:

Instrument Administrator

- Configure the RICE software for instruments, and allow Remote Users secure access.
- Monitors active remote instrumentation sessions and controls remote access to the instruments i.e., which Remote User can observe and/or control the Raman-FTIR.

Remote Users

- Multiple Remote Users see who are connected to the instrument and can communicate with the Operator controlling the Raman-FTIR in a VNC session during an experiment run
- They can collaborate using voice chat and text-chat conferences integrated within RICE, and pass the control amongst each other
- They can replicate the dual-desktop setup at a local instrument at the remote site, and have "at-the-instrument" experience using the RICE software
- They can be "network-aware" and know whether control lags in a remote instrumentation session are due to actual instrument device delays or network congestion delays

2 OSC's Remote Instrumentation Collaboration Environment (RICE)

OSC has developed a peer-to-peer remote observation and remote operation software application called Remote Instrumentation Collaboration Environment (RICE) for the Raman-FTIR. RICE is based on the open-source Ultra VNC solution for the Windows operating system but has several enhancements on both the client and server sides. The enhancements are customizable and are targeted to handle collaborative tasks such as voice conferences and text-chat between multiple participants during RI sessions in a self-contained manner. Figure 2 shows the RICE client software in an active multi-user session on the Raman-FTIR. RICE supports features such as: video quality adjustment slider, VoIP, text-chat, multi-user presence, network health monitoring, and remote dual-desktop resolution.

The video quality adjustment slider is used to manually adjust frame rates and video encoding rates to suit the end-to-end network bandwidth between the remote user site and instrument lab. To handle peer-to-peer VoIP as well as VoIP conferences, the open-source Ohphone and OpenMCU solutions have been integrated into RICE. We developed a text-chat feature in RICE using a custom session signaling protocol (SSP). The text-chat uses colored text to distinguish messages of the local user from the remote users. The self-contained VoIP and text-chat features are useful for the participants to communicate control-lock exchanges and other messages in an RI session. The SSP protocol is also used to provide the multi-user presence feature that displays and updates in real-time, the names and roles of the users connected. The presence feature is coupled with a control-lock passing feature that grants instrument control to a single user at any given instant. The restrictions are enforced based on the user roles in an RI session: "administrator", "viewer" or "controller". By default, the administrator always has control privileges, and has the ability to pass another session control-lock to any one of the viewers. A remote user who is a controller can directly pass the control-lock to any other remote user via the RICE client interface, without intervention of the administrator.

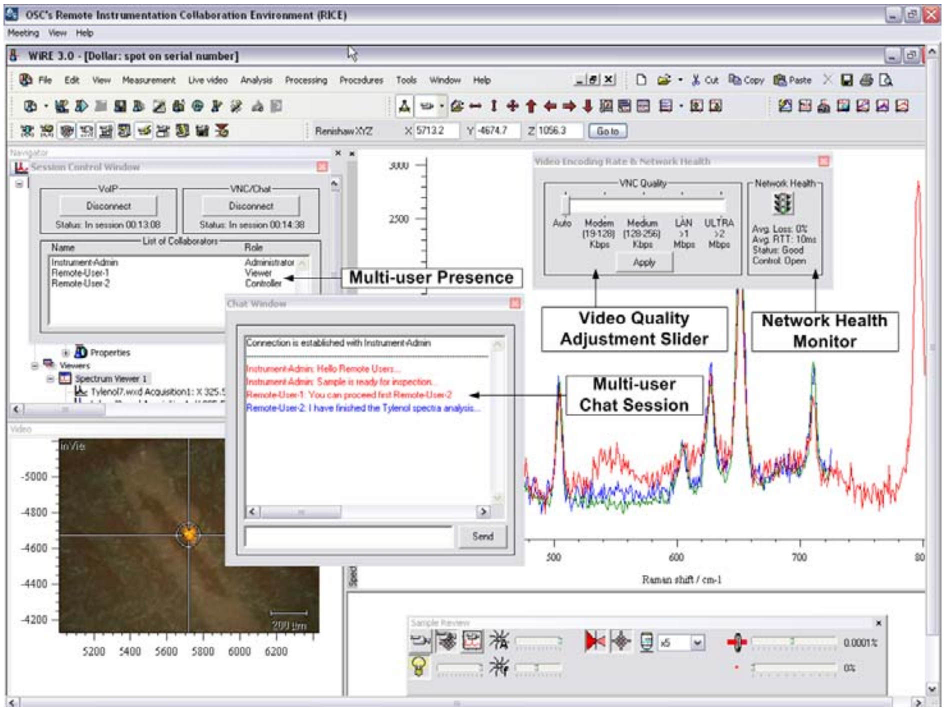

Figure 2: Screenshot of OSC's RICE customized for Raman-FTIR Microprobe

The network health monitor in RICE shows real-time network status in terms of round-trip delay and loss metrics. The network status grades indicated by a traffic light graphic are: "Good" (green color), "Acceptable" (amber color), and "Poor" (red color). The monitoring is coupled with a network performance anomaly detection scheme that is based on the "plateau detector algorithm". Once an anomaly is detected, RICE warns and blocks user's control-actions during impending and extreme network congestion periods, respectively. Thus, the control status can be either "open", "warning", or "blocked" depending on the network congestion levels. The motivation for this feature in RICE is as follows: if adequate end-to-end bandwidth is not provisioned, network congestion may result that causes time-lag and packet drop events, which impair the control software screen images at the remote user end. This in turn could lead to improper user control of the instruments mechanical moving parts. Such improper user control may ultimately result in physical equipment damages that are prohibitively expensive to fix. Although 'limit switches' in some well-designed instruments mitigate damage due to such user error, there are always unexpected cases where such limit switches may not be effective.

The remote dual-desktop resolution feature allows a remote user to mimic an extended desktop setup with dual-monitors at the instrument computer. The extended desktop provides additional real-estate for users to run multiple application programs simultaneously. The openly-available Ultra VNC distribution does not support dual-desktop resolution at the remote VNC client as shown in Figure 3. We developed a software-patch for the Ultra VNC in RICE that increases the display resolution geometry to successfully render the dual-desktop resolution at the remote VNC client as shown in Figure 4.

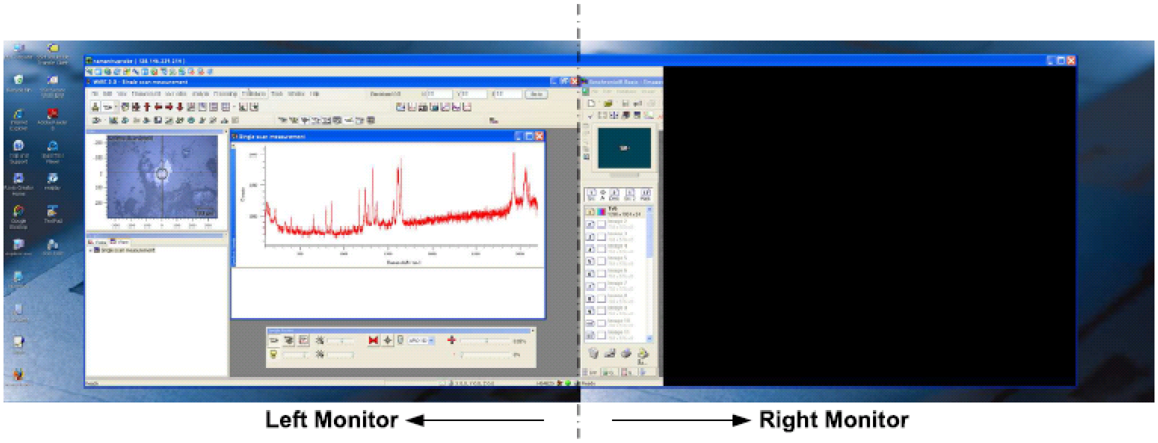

Figure 3: Problem with Dual-desktop resolution with Ultra VNC

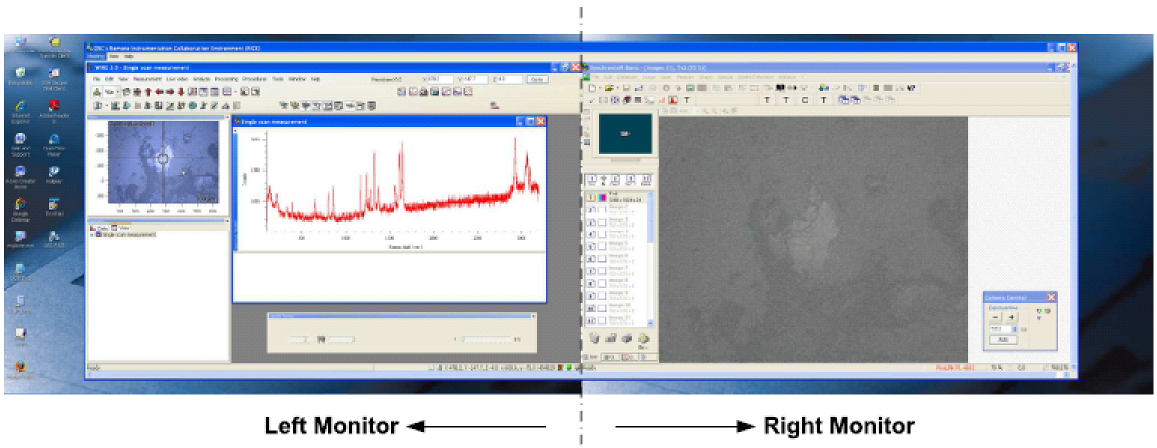

Figure 4: Increased Dual-desktop resolution with RICE

The RICE software has been developed with careful considerations to: instrument safety, network and data security, open-standards without licensing restrictions, extensibility to other instruments, and ease of on-going maintenance. It functions on computers using the Windows operating system. RICE can be used by businesses, educators and academics, and to the extent possible, does not include any sub-components with licensing terms that would bar such use.

3 Challenges Addressed and Open Issues

We deployed our RICE solution on the Raman-FTIR (shown in Figure 1) and conducted several sets of LAN tests. One set of LAN tests we completed successfully involved running the RICE clients using both "Administrator" and "General" login accounts on computers with Windows XP as well as Windows Vista operating systems (OS). In addition, we successfully tested the RICE clients in a LAN using both 32-bit as well as 64-bit Windows Vista OS computers.

Although there were no major OS portability issues, we faced several display related problems. One of the major problems was the Ultra VNC problem with dual-screen resolution that we discovered and resolved as explained in Section 2. Another display problem occurred when the instrument computer and remote computer resolutions did not match. This resulted in visible gray regions in the RICE client in both fullscreen and dual-screen modes. Also, sometimes the RICE client had refresh problems due to the limitations in the Ultra VNC auto-refresh implementation. We devised a "reset" feature in RICE that disconnected and reconnected the RICE client without affecting the collaboration tools features. Although this solved the refresh problem on the RICE client side, a new overlay error message problem arose on the instrument computer (RICE server side) as shown in Figure 5. The error message grayed-out the instrument camera feed, whose restoration required restarting the instrument control software application. This problem was determined to be due to the instrument vendor implementation of the instrument control-software, and the instrument vendor was notified to provide a problem resolution. We noted that this problem is one of the many problems that the instrument vendors are facing with their instruments being increasingly cyber-enabled, unlike in the past where cyber-enabling was not a common requirement in instrument labs.

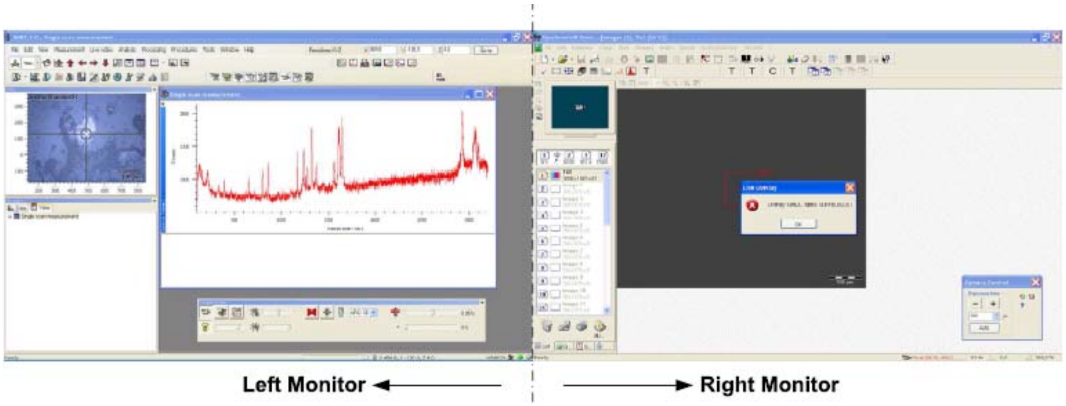

Figure 5: Local overlay error message on instrument PC upon remote RICE client reset

4 Outreach Activities

Presentations/Demonstrations:

[1] "OSU's Cyber-enabled Raman-FTIR Microprobe", *IEEE/ACM Annual Supercomputing Conference* - Demo Session, November 13 – 16, 2007.

[2] "Remote Instrumentation Collaborations in Ohio", I*nternet2 Fall Member Meeting* – Demo Session, *K-20 Advisory Committee Meeting* – Plenary Talk, New Orleans, LA, October 13 – 16, 2008.

[3] "Cyber-enabled Instrumentation Challenges and Future Directions", *National Science Foundation Cyber-enabled Instrumentation Workshop* – Plenary Talk, Arlington, VA, July 17, 2008.

Peer-reviewed Publication:

[1] Prasad Calyam, Abdul Kalash, Neil Ludban, Sowmya Gopalan, Siddharth Samsi, Karen Tomko, David E. Hudak, Ashok Krishnamurthy, "Experiences from Cyberinfrastructure Development for Multi-user Remote Instrumentation", *4th IEEE International Conference on e-Science*, 2008.

[2] Prasad Calyam, Abdul Kalash, Ramya Gopalan, Sowmya Gopalan, Ashok Krishnamurthy, "RICE: A Reliable and Efficient Remote Instrumentation Collaboration Environment", *Journal of Advances in Multimedia's special issue on "Multimedia Immersive Technologies and Networking"*, 2008.

Press Releases:
[1] "Remote use of Scientific Instruments Expands Research, Education", *OSC Annual Research Report* – http://www.osc.edu/research/report/data_remote.shtml

[2] "Cyberinfrastructure Tools Improve Remote Use of Scientific Instruments", *HPCwire* – http://www.hpcwire.com/offthewire/Cyberinfrastructure_Tools_Improve_Remote_Use_of_Scientific_Instruments.html; Same press release also published in following news outlets: – www.supercomputingonline.com, www.esciencenews.com, www.innovations-report.com, www.newswise.com, www.silobreaker.com, http://technews.acm.org

[3] "Future Watch: A Better View From Afar" - *PC Magazine*, Volume 26, Number 25, 2007.