Live Demonstration:

Femto- to-Macro Scale Interdisciplinary Sensing with Tensioned Metastable Fluid Detectors

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Abstract—*Live interaction, interdisciplinary multi-physics demonstrations using the tensioned metastable fluid detector (TMFD) sensor systems are proposed. TMFDs utilize centrifugal-acoustic forcing to place ordinary liquids like water into sub-zero (i.e., below vacuum) pressure states of metastability such that interacting subatomic scale particles, or even eV photons can be detected via visible-audible transient bubbles that nucleate from nm scales growing to visible mm scales. Interactive experiments will cover diverse areas such as: nuclear physics (detecting neutrons – tell-tale signal from U/Pu fission using a unique NRC-licensed public use neutron source, study of cosmic rays); health-nuclear medicine (measuring of lung-cancer causing Radon in air at ultra-trace 1 part in 10^{17}); Optics (monitoring and tracking a nanosecond pulsed laser beam); Acoustics-Piezoelectrics-Fluidics-Heat Transfer-.Mechanics.*

Keywords—TMFD, Fluidics, Acoustics, Radiation, Optics

I. Introduction & Background

Ordinary fluids like water at room temperature can indeed be placed under tension, even negative (Pneg) pressures (yes – even below perfect vacuum) as scientifically confirmed only a few decades ago leading to the novel TMFD sensor class [1]. Briefly, tensioned fluids are in state of metastability; their intermolecular bonds weakened such that, select stimuli types can "poke" holes into them to create transient bubbles that can rapidly (within μs) grow to states that are visible-audible to humans. Amazingly, conventionally hard to detect sub-atomic neutral particles like neutrons or ions (tell-tale signatures from U/Pu nuclear fission) can be now detected with unparalleled intrinsic efficiency [1-2]. Stimuli types may also include ordinary UV-IR photons. The scientific principles and potential transformational uses have been published elsewhere [e.g., 1-2]. Unlike complex/expensive conventional sensors for radiation-photon detection which rely on extensive electronc trains, PMTs, scintillators, etc., TMFDs are based on intuitive, centrifugal force as from common rotary tools, and/or resonant mode acoustic vibrations from piezo-electric elements. Two distinct forms of hand portable, table-top systems: C(Centrifugal)-TMFDs and Acoustic(A)-TMFD systems will be used for demonstrations and hands-on experiences.

Table-top CTMFD and ATMFD sensor setups are shown in Figs. 1a, 1b, respectively – AC/DC powered.

Figure 1a. Centrifugal Tensioned Metastable Fluid Detector Setup/Operation **movie clip** http://web.ics.purdue.edu/~ahagen/link_1.mp4	Figure 1b. Acoustically Tensioned Metastable Fluid Detector Setup/Operation **movie clip** http://web.ics.purdue.edu/~ahagen/link_2.mp4

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II. Interactive Demonstrations

A. Special Nuclear Material (SNM) Identification

Imagine a sub-atomic 10^{-27} kg (almost mass-less) particle with only ~10^{-12} J making a liquid boil on demand in space-time, without any superheat at ~20C!!! Merely, by changing the Pneg tensioned fluid state. Such sensing capability is unparalleled. Using USNRC's first of kind license to Purdue, now for the first time enables our small (~10cc) on-ff source of neutrons for public demonstrations- we will show that state-of-art sensors are ineffective. Then, we demonstrate how the simple macro-scale TMFD apparatus allows a lay-person to spectroscopically detect, in-effect visibly see/hear neutrons via recordable bubble pops. (http://web.ics.purdue.edu/~ahagen/link_1.mp4) - **movie clip.**

B. Tracking a laser beam with directionality and intensity

Imagine studying optical phenomena via fluidics and heat transfer to also sense and map transient pressure profiles [1,3] in non-contact mode!!! Ref. 1 (Fig. 9) shows a track of bubbles delineating the directional characterization of a common ns UV pulse(~0.3 mJ) at only 1bar below vacuum (-10^5 Pa). (http://web.ics.purdue.edu/~ahagen/link_3.mp4) - **movie clip.**.

C. Real-time Radon in air detection with TMFDs

Radon is a gas that enters homes/dwellings at ultra trace quantities (1:10^{17}) but which, according to the EPA, causes 25,000 lung cancer deaths in the USA alone. Conventional (~$10K+) Rn sensors are complex, unaffordable, and require days/weeks to provide reliable estimates. Live demonstration will be given using CTMFDs (http://web.ics.purdue.edu/~ahagen/link_1.mp4- **movie clip**) on how Rn in air may also be detected in near real time.

III. Visitor Experience

Visitors will handle TMFDs hands-on, learn novel sensing for wide-ranging arenas: terrorism; portal screening; medicine; energy; interdisciplinary engineering sensing applications.

References

[1] R. P. Taleyarkhan, J. Lapinskas, Y. Xu, "Tensioned metastable fluids and nanoscale interactions with external stimuli.." Nucl. Engr. Des., 238 (2008) 1820-1827.

[2] B. Archambault et al., "Transformational Nuclear Sensors – Real-time monitoring of WMDs, Risk Assessment and Response," IEEE HST-2010 978-1-4244-6046/10 (2010) 421-427.

[3] A. Hagen et al.,, "Characterization and optimization of a tensioned metastable fluid nuclear particle sensor using laser based profilometry," ASME Journal of Nuclear Engineering and Radiation Sci 1 (4), 041004-1-10 (2015).