EPISODE FORTY ONE OF "ARMED WITH SCIENCE: RESEARCH APPLICATIONS FOR THE MODERN MILITARY," A DEPARTMENT OF DEFENSE WEBCAST SUBJECT: QUANTUM GHOST IMAGING HOST: DR. JOHN OHAB GUEST: RON MEYERS, ARMY RESEARCH LABORATORY TIME: 2:00 P.M. EDT DATE: WEDNESDAY, OCTOBER 28, 2009

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(Intro music begins.)

ANNOUNCER: "Armed with Science: Research and Applications for the Modern Military" is a weekly Webcast that discusses cutting-edge science and technology and how they apply to military operations.

Each week we will interview scientists, administrators, and operators to educate and inform our listeners about the importance of science and technology to the modern military.

(Intro music ends.) DR. OHAB: Good afternoon and welcome to episode number 41 of "Armed with Science: Research and Applications for the Modern Military," on Wednesday, October 28th, 2009.

I am Dr. John Ohab at the Office of the Assistant Secretary of Defense for Public Affairs.

As you know, Halloween is fast approaching. I will attempt, to the best of my ability, to spare our listeners any ridiculous Halloween puns. This is a science show, after all.

But in the true Halloween spirit, our focus today is on quantum ghost imaging, a new way of seeing objects that were once hidden from sight.

We're joined by Ron Meyers, quantum physicist at the Army Research Laboratory, whose team is credited with taking quantum ghost imaging from a physics curiosity and making it a discipline with many important applications.

Ron, you are our first quantum physicist on the program this year. Thank you for joining us on our Halloween science special.

How are you today?

MR. MEYERS: I'm fine. Thank you for the fine greeting.

DR. OHAB: As always, a quick note to our listeners. I encourage you to tweet your questions to @armedwscience. Get those in sooner than later and we'll do our best to have your questions answered by end of the program.

Now, Ron, there are certain kinds of science -- quantum physics perhaps included -- that are probably more frightening to people than anything associated with Halloween.

Can you get us started by providing, on basic terms, about the field of quantum physics?

MR. MEYERS: Okay. Quantum physics is the modern theory of the universe -- how atoms, photons, electrons interact. And it's different from our view of physics many years ago.

It was developed essentially by such scientists as Planck, Einstein, Schrödinger, de Broglie, Dirac and Feynman. And these led to Nobel Prizes and really did the underpinnings of modern physics.

Quantum particles have -- are different than what we view particles as. A baseball would be thrown straight or maybe with a little curve. Quantum particles have both wave and particle properties. And essentially, the waves give a -- lead to an interference patterns. Essentially the description is that the universe is based on probabilities or quantum probabilities.

And quantum has already given us much that affects our lives, such as the periodic table, which describes chemistry and predicts the properties of chemicals.

Also, quantum describes the radiation spectrum, that the radiation energy is quantized. So that's where the name came from, essentially.

DR. OHAB: And when you say quantize, what do you mean by that?

MR. MEYERS: It means that the radiation comes at different levels, noncontinuous levels, different discrete levels.

DR. OHAB: Now, you're currently working at the Army Research Lab, and you've been a physicist for more than 30 years -- as I mentioned, the first quantum physicist we've had on the program.

Can you tell us about your scientific background and training?

MR. MEYERS: Well, I'm a physicist, as you said. And I've also done a lot of work in atmospheric physics and nonlinear mathematics research.

At Brookhaven National Laboratory, I did the first air pollution model for the entire United States. I did that under the auspices of the White House quite a long time ago, under President Jimmy Carter.

DR. OHAB: Now, is it common -- I'm sorry.

MR. MEYERS: Well, what I would like to say is that that gave me some background, and I wanted to see how the -- how we can see through the atmosphere, having done the work on the atmosphere.

For example, when we do imaging through the atmosphere over long distances, we're affected by turbulence and obscurance, fogs, clouds.

And being a physicist, I was always interested in the fundamental laws of the universe, and that really led me to quantum science and technologies. I noticed that the diffusion equation that's used in the atmosphere is mathematically related to the quantum Schrödinger equation. So that stimulated my interest.

And so I looked into it in more detail. I'm trying to leverage quantum properties for applications.

DR. OHAB: Would you say that it's common for there to be synergies between things like quantum science and other scientific disciplines, or is this a rare combination that you've described, with the atmospheric research? MR. MEYERS: Well, I think it's getting more common that the scientists that we're seeing now have backgrounds in many areas -- for example, in physics and biology and chemistry. And the discoveries are really made at the -- tend to be made at the interfaces between these.

DR. OHAB: Now, at Army Research Lab, you and your team have really broken some new ground in a discipline known as quantum ghost imaging. Can you tell us about that?

MR. MEYERS: Well, ghost imaging, it's a new type of imaging that uses quantum measurements. And normally, it has two sensors.

And one sensor is a camera, and it looks at the light source. And the second sensor is essentially a sensitive light meter, and it looks at the object. And these can be looking in different directions.

That is, you can have the camera looking at the sun or at a laser, and the light meter is looking at your object, which might be a soldier or a tank or an airplane, for example.

And a number of these measurements are made. They're made with great precision. The information is put together and out comes the ghost image.

So essentially, the ghost image is computed. It's not seen directly.

DR. OHAB: Is it a reproduction of the image that you've been focusing on?

MR. MEYERS: Well, it will look similar to the object that the light meter is looking at. So we're not -- the light meter doesn't pick up any spatial information from the object. So this is really --

But the computation will see the object. So it is really different from conventional imaging where a camera looks at the target or the object. Here, we look at the light source, and that gives us some advantages.

DR. OHAB: Yeah. Could you go into it further? What makes this quantum, as opposed to a traditional imaging?

MR. MEYERS: Well, what makes it quantum is that the connection between the light source photon and the photons that hit the object and reflect and scatter off the object, the connection can be described by wave functions, which are essentially the probability amplitudes.

Remember I talked about quantum essentially dealing with probabilities, and we're able to formulate this properly.

Now photons are very small quantum particles, and so we may be dealing in the ultraviolet at, let's say, 200 nanometers wavelengths, or in the infrared at one micron wavelength.

So we're dealing with small particles, and our measurements have to be very precise and very accurate. And so we're able to do measurements to a billionth of a second, for example.

Now, we can actually get -- use some slower measurements than that in some cases, and we're developing technology to run the spectrum of time sensing.

DR. OHAB: Now, it sounds like you've been exploring quantum ghost imaging for a while. But in a sense, it kind of sounds like something that might come out of a science fiction movie. How did this idea originally come about?

MR. MEYERS: Well, there was initial research in the direction of ghost imaging, and that was by Professor Yan-Hua Shih and some of his students and colleagues. He was at the University of -- or is at the University of Maryland in Baltimore County.

So in 1995, Todd Pittman worked on research of ghost imaging, and he was essentially looking at an effect by Einstein. This is called the EPR -- Einstein-Podolsky-Rosen -- effect. And he was able to --

Todd Pittman, who is now a professor at UMBC, was able to ghost image a mask, essentially. There was holes of a particular shape with the letters UMBC, and he made measurements with what we call a photon bucket detector, or a sensitive light meter, behind the holes in the target. And the illumination was by a laser.

And then he made other measurements, very detailed measurements of where the laser light, which had been split into another path, where

it was coming from. So what happened was that he was able to see the image.

But they were not able to do anything like looking at an opaque object such as we did. So we did the first ghost imaging in our laboratory of an opaque object.

DR. OHAB: And how would you characterize this kind of research? What are the day-to-day activities in a quantum physics lab?

MR. MEYERS: (Laughs.) Well, right now we're doing laboratory measurements, but in the future we'll be doing measurements in the field. So we're setting up targets.

We have lasers, for example. Laser goes through a beam splitter on an optical table. The laser is made chaotic by rotating a fast-revolving ground glass in front of the laser so the laser light transmits through the ground glass to make it highly chaotic and so it has a lot of fluctuations.

And we break that into two paths. One path is -- we call the reference path. We measure that. That's looking at the light source. The other path is bouncing off -- in our case, it was -- a toy soldier was our first target.

We put that information together with the data stream from the fast sensors, and we end up with an image of the object.

We're also putting obstacles in front, such as cloudy glass, such as heating the air and causing a lot of turbulence along the path to see that we can see through the turbulence with this technique, and so far that's working very well. DR. OHAB: Now, I understand you recently won an Army Research and Development Achievement Award. Could you tell us a little bit about that?

MR. MEYERS: Well, the -- this is an award that's given by the Army for outstanding research in some areas. And what it means to us is there is some recognition that our efforts are being looked at seriously and are being looked at for future applications.

We published an article in Physical Review A in 2008, and the article was "Ghost Imaging by Measurement of Reflected Photons." And that proved to be important. It received a lot of review, and it's generally recognized that this is showing that ghost imaging can be an important application in the future.

DR. OHAB: What kind of response have you had from the international scientific community?

MR. MEYERS: Well, we think that's been very good. I helped chair a conference in San Diego for the organization SPIE, which is a professional society that deals with light and photonics.

And so I chair this meeting every year. It's an international meeting. We get people from over 20 countries, scientists, attending this. And we have discussions on and presentations of research in quantum communications and quantum imaging.

And so that -- we've gotten a good response from those scientists, and we're -- have been acknowledged in the literature and their publications that this work is important.

And of course, they contribute research in these directions also.

DR. OHAB: Now, I'm going to break out the old "Armed with Science" crystal ball here for a second.

When you look into that, how do you see this being used in the future?

MR. MEYERS: Well, I think, or I would hope, in a few years that we have a soldier using a quantum ghost imaging imager to look through battlefield smoke and identifying friend or foe.

Also, I would think that there are some applications of satellites being able to see through thin clouds and fog and do imaging, and getting images in cases where current technology cannot see any images. So those are examples.

I also see applications in the medical field, such as with x-rays and ghost imaging microscopes. There are some advantages here. It looks like you can get higher resolution. With ghost imaging, you can get higher resolution and you can beat the effects of what we call aperture-limited imaging. So one can see higher resolution, essentially. Even in lensless cases where we don't use lenses, it's as if you have a large lens. So you could put such devices and do imaging in the body. You could do imaging of the body externally using x-rays, but with much lower x-ray insult to the human tissue, as an example.

So with ghost imaging, by placement of the sensors in certain locations, one essentially can get focusing. So that works. That also works for, let's say, for x-rays. Where it's difficult to focus x-rays, you could get x-ray focuses. So I see applications in those areas.

DR. OHAB: Yeah. It seems like there are some obvious applications that span both military use and out into everyday life.

MR. MEYERS: Right. There could be many societal applications.

DR. OHAB: So what about timing? When do you think this will actually be applied to tangible situations?

MR. MEYERS: Well, I would think that the first applications -- we're not exactly sure. It depends on, really, our progress.

But I would expect in a few years that we can avail ourselves of the technology for applications.

DR. OHAB: So what would you say is the biggest challenge in doing this kind of research?

MR. MEYERS: The biggest challenge is really getting good measurements.

When you do a new science, you really need to perform your measurements at -- with high quality so the experiments can be repeated by others, so that we understand the parameter space that we're working in, so we can do designs of more efficient, smaller, more robust equipment in the future, okay? So, getting good measurements.

Now, at the Army Research Laboratory, we've been very lucky that we've been able to be funded to get very high quality instruments, such as single-photon detectors, such as very sensitive cameras and light sensors, quick measurement techniques where we can measure the coincidence of two photons, make sure that they're measured at the same time, even though they're at great distances apart.

So this allows us to bring out the quantum properties.

DR. OHAB: Of course, this research is only one part of the research that goes on at the Army Research Laboratory. Can you tell us just a little bit more about the organization?

MR. MEYERS: Well, the Army Research Laboratory is essentially the corporate laboratory for the Army. And it does innovative science, technology, analyses, in order to support military operations, all different types, from helicopter operations to small- unit, tactical operations.

And what we try to do is come up with innovative solutions that will support the war fighter. And when we can, we also spin off our technology for domestic uses.

DR. OHAB: Now, as you mentioned earlier, you have over 30 years of experience in the field. How has working in the Army actually benefited you as a scientist? MR. MEYERS: Well, I think it's really the best place to work for a scientist. That is, you're given responsibility at a young age, and you're able to go as far as your thoughts and your abilities can take you.

So it's a very stimulating environment. Really, the sky's the limit, working for the Army.

DR. OHAB: As we wrap up the show today, do you have any final thoughts or comments that you'd like to add?

MR. MEYERS: Well, I would say I'm very grateful to be working at the Army Research Laboratory, which supports the war fighter. I think

that's -- we're in two wars right now, and we're -- if you look back on our history, we've always been in important struggles for freedom.

And it gives me and my colleagues great satisfaction to be able to work in these areas, to support the war fighter and defense of the country.

DR. OHAB: Today's guest is Ron Meyers, quantum physicist at the Army Research Laboratory.

Thank you again for your time today, and best of luck with the research as it progresses.

MR. MEYERS: Thank you. It was quite enjoyable.

DR. OHAB: Listeners, please tune in next Wednesday, November 4th, when we are joined by Dr. Thomas Meitzler, scientist at the U.S. Army Tank-Automotive Research Development and Engineering Center, or TARDEC, who will discuss sensor-enhanced armor that could deliver real-time information about a vehicle's health.

His work could eventually provide soldiers with more safety and better situational awareness.

Thank you again. I hope you have a wonderful and safe Halloween. I am Dr. John Ohab, and you've been scienced.

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