Dr. Murty
The Wizard of Light

Dr. Murty V. Mantravadi was born in India in 1929 and had educational and professional careers in India and United States and for a short period in Mexico. He obtained B.Sc. with majors in Mathematics, Physics and Chemistry from Andhra Christian College in Guntur, India in 1949. He then obtained a Diploma in Instrument Technology (D.M.I.T.) from Madras Institute of Technology, Madras, India in 1952. He was a lecturer at the same institute until 1955. He enrolled in the Ph.D program of Institute of Optics, University of Rochester, at Rochester, New York early in 1956, earning a Ph.D. degree in Optical Engineering in 1959. From 1959 till 1964 he was on the faculty of the Institute of Optics teaching courses and doing research in Optical Testing, Interferometry, Geometrical and Physical Optics and lab courses. At the end of 1964, he went back to India and was Professor of Instrument Technology at Madras Institute of Technology till 1966. From 1966-1982 he was head of the Optics Section of the Spectroscopy Division of Bhabha Atomic Research Center at Bombay, where he was involved in Optical Testing, setting up the optics shop, building various instruments for the Atomic Energy department, Spectroscopy and research. Dr. Murty was a visiting Professor for short periods, to the Instituto Nacional de Astronomica, Optica y Electronica in Puebla, Mexico, also to the U of R Institute of Optics in Rochester, New York in 1973 and Centro de Investigacion en Optica in Leon, Mexico in 1980. During his Mexican visits, he collaborated with Dr. Daniel Malacara by contributing two chapters on Optical Testing and Interferometery to the book OPTICAL SHOP TESTING, edited by Dr. Malacara, a book with which some OSSC members may be familiar. In 1982 he left India and joined the Centro de Investigacion en Optica, Leon, Mexico as a professor till 1984. He came back to United States in 1984 and worked at Halo Technologies, Costa Mesa, California as Chief Scientist till 1986 and as Professor of Physics at Alabama A&M University at Huntsville, Alabama till 1987. He then joined Northrop Corporation, Southern California in 1987 as Research Engineer and retired from Northrop Grumman at the end of 1994.

Dr. Murty has presented at various conferences and published in refereed journals such as JOSA, Applied Optics, SPIE Optical Engineering, etc. more than 120 papers relating to Optical Testing, Interferometry, diffraction, spectrometers, optical devices and gadgets, etc. He was the originator of the shear plate testing method to check for aberration and collimation of a laser beam. The method was devised almost immediately after the He-Ne laser was available in 1963 and the publication was made subsequently by him in Applied Optics. Dr. Murty is a Fellow of Optical Society of America, a Fellow of the SPIE, a Fellow of the Indian Academy of Sciences and a Fellow of the Optical Society of India.

As an aside to the name of Dr. Murty, his full name given by his parents at birth was Mantravadi Venkata Radha Krishna Murty. Mantravadi is the surname and it is traditional to write it first and also use an initial for it. When the name is long, initials are used for other parts of the given name. So, Dr. Murty was known for a long time and in his publications as M.V.R.K.Murty. After he became naturalized as United States citizen, he has styled his name as Murty V. Mantravadi.

Dr. Murty Mantravadi lives with his wife Suryaprabha in Carson, California. The Murty's have 6 children (three on the East Coast, one in Florida and two close by in Southern California.)

The term OPTRICKS is somewhat based on Dr. Murty's interest in optical phenomena which seem baffling at first but can be explained after some thought and the use of optical principles. Dr. Murty published a series of OPTRICKS: Tricks and simple experiments you can do in Optics FOR YOUNG READERS in Science Today Magazine in the mid 1970's.

OPTRICKS Suitcase

An Educational Outreach Presentation Guide

With Inspiration By:

Dr. Murty
The Wizard of Light

TACO BELL DISCOVERY SCIENCE CENTER

OPTICAL SOCIETY OF SOUTHERN CALIFORNIA

Optical Society of America Rochester Section

The Optics Institute Of Southern California

SPIE The International Society for Optical Engineering

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11) Tips on Ending (You Are Always Rushed)

While the students put away their take home theme packets, thank them for inviting you and ask if there are any more questions. Are there things that they want you to clarify or repeat?

The teacher may have to start up with another class five minutes after this one leaves, so be prepared to throw all of your props into your **Optricks Suitcase** and make a hasty retreat.

11) Acknowledgements

Much effort has been devoted to the development of the **OPTRICKS Suitcase**. Over 6000 theme packets have been distributed across the country. With a recent Activity Grant awarded by OSA's Member & Education Services Council and The International Optical Engineering Society (SPIE) additional financial support from The Optical Society of Southern California (OSSC), this effort will continue. I (DS) acknowledge many individuals for their contributions: Steve Jacobs and his colleagues from the University of Rochester and the Rochester Section of the OSA, who developed the original Optics Suitcase. The original Optics Suitcase Presentation Guide acknowledges the original collaborators.

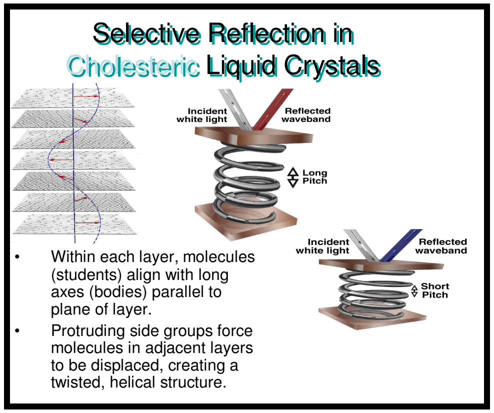
Southern California collaborators include Dr. Murty – The Wizard of Light, who was a professor at the Institute of Optics at the University of Rochester before he relocated to Southern California and is a Fellow of the OSSC. Other OSSC members and volunteers include: Reddy Chirra, Susan Raffensperger, Tom Godfrey, Tom Ha, Rodger Winn, Mary Brown , Arnie Bazensky, Larry DeShazer, Victor Kardos, Charles Gaugh, Michael Silberman, Ana Maria Silberman and our friends Joe Adams, Janet Yamaguci, Kellee Preston and Roxy Nava at the Discovery Science Center whose volunteers assembled many Theme Packets for these kits.

Also, our friends at THINK Together, who allowed us into their after school programs to present and further develop these lessons. The UC Irvine Center for Educational Partnership (CFEP) Gifted Student Academy's Director Darlene Boyd and her staff for letting us teach at their summer programs for three (3) years now. The CFEP's MESA (Math Engineering Science Achievement) program Director Jaime de Razo and his staff, who is administering the Hands-On Optics program and has provided many forums of different sizes to bring optics outreach programs to students in Southern California.

At the Optical Society of America, Jason Briggs, Education Specialist, has been instrumental in helping not only with the OPTRICKS Suitcase, but with the OISC in general. At SPIE, June Thompson and Shelia Sandiford, have been likewise supportive of the OISC in general and the OPTRICKS Suitcase in particular.

• Most of the colors in white light pass right through cool liquid crystal film and are absorbed in the black paper. The patch appears black.

• As body temperature heats up the patch, the liquid crystal "springs" get tighter and they "selectively" reflect the red light part of the white room lights. As the temperature climbs, yellow, then green, and finally blue light are reflected. This is as tight as this liquid crystal gets. *[See Figure 9.]*



• The effect is reversible. Students may put their patches on an ice cube or under a mug of hot cocoa to see the effect of selective reflection. Give a warning that the sheet should not be folded or marked with a sharp object like a pencil.

A Subtle Message About Smoking Transparency

• Mention that doctors study circulation in the body with liquid crystals. On the left side of the picture, the blue color of the man's hand shows good blood circulation to the fingers. The picture on the right side shows that, after smoking one cigarette, the man's fingers reflect green because of reduced circulation. Nicotine constricts the blood vessels.

Optical Society of America
Rochester Section

A Subtle Message About Smoking

blue (warm) fingers for normal blood flow

green (cooler) fingers from nicotine in cigarettes that restricts flow to extremities

• End by reminding the students that liquid crystals are found in every thing from cell phones to watches to laptop computers to GameBoys. What would the information age be like without the engineers and scientists who developed liquid crystals?

1) List of Equipment and Supplies

Your OPTRICKS Suitcase contains two types of supplies: reusable and give-away.

Reusable Supplies:

Quantity	Item
1	black suitcase with room for other items you may add to customize your presentation
1	set of Arbor Scientific "Happy and Unhappy" balls and fact sheet
1	Slinky Jr.
1	100 mm diameter silicon wafer, one side polished to a "mirror" finish
2	optical glass biconvex lenses
2	7" x 12" pieces of high-quality, sheet polarizer (no blue leak)
4	transparent plastic cups
2	Large Fresnel lenses - different focal lengths
1	X-Light flashing rainbow
1	set of plastice utensils - 1 fork, 1 knife, 1 spoon

Giveaway Supplies:

Quantity	Item
	Take Home Theme Packets
75	Rainbow Peephole™ - Color by Redirecting (Diffraction)
75	Magic Patch - Color by Selective Reflection (Liquid Crystals)
75	Periodic Table of Elements / OPTRICKS Suitcase Info Sheet
75	Magic Dots - Lens

Visit http://oisc.net for more information and materials.

Contents for the Optricks Suitcase.

10) Magic Patch - Color by Selective Reflection (Liquid Crystals)

Remind the students that you have demonstrated how to see the colors in white light through diffraction and polarized transmission. Making sure that everyone is looking at you, take the **large sheet of microencapsulated liquid crystal** and place it against your face, shiny side out. [*If you wear glasses, remove them first.*]

• Wait a bit for the "oohs" and "ahs" to die out, then ask... "Where do the colors come from?" [*If some students say the heat from your face, answer no.*]

• Explain that the colors come from the white room lights reflecting off the black "paper".

• As the teacher passes out the **Magic Patch Theme Packets**, explain that the paper has liquid crystal fluid trapped, or encapsulated, against the shiny side. [*Note: The large demo sheet and the give-away patches are made from the same liquid crystal material. The material goes through a complete color change with a temperature change of 77° F to 86° F. If the room is warm, you may have to find a way to enable students to cool their patches down. Water or the cold floor work well.*]

• Suggest that each student determine if she (he) is a vampire by placing the magic patch on the inside of her (his) wrist. [*Vampires are the living dead and give off no heat.*]

• Ask if anyone can "see a vein". [*This would be characterized by a blue line.*] To explain selective reflection in liquid crystals and "mood rings", you may use the set of transparencies included as follows:

"Liquid Crystals in Education" Transparency

• Students are laying on the grass, disguised as liquid crystal molecules. In liquid crystals, the molecules show a high degree of organization and alignment in some regular order.

"Selective Reflection in Cholesteric Liquid Crystals" Transparency

• If we try to stack students (or liquid crystal molecules) in a series of layers on top of each other, they tend to twist as shown on the left in Figure 8. The heads of the students point in a spiral direction as we move up through the structure, like a spring.
• Think of the liquid crystals in the black sheet as springs. When they are cool, the springs are relaxed with a long pitch (or twist). [*Refer to the right side of the picture.*]

Students, and they should be able to see you. Ask them to make a sandwich in the same way with their dark pieces of plastic.

• During the “oohs” and “ahs”, reveal that each dark plastic has a secret code on its surface in the form of small lines. Combining the plastics so that the lines are parallel makes it possible to see though them. Combining with lines perpendicular, or “crossed”, blocks the light. Identify the plastics as linear polarizers. One plastic held up to the room lights causes the unpolarized white light to become linearly polarized. Once the light is linearly polarized, it vibrates in one plane, and it is either transmitted or absorbed by the second plastic polarizer. Polarized sunglasses are made of this plastic.

• Have the teacher turn off the lights. Place the large polarizers on the overhead projector and demonstrate how they polarize and extinguish the white light from the projector. Separate the crossed polarizers at four corners with the **plastic cups** to make a **polariscope**, place the **plastic ware** inside, stand back, and enjoy the excitement.

• Ask where the color comes from. [*You might get some correct answers.*]

• Explain that stresses inside of transparent materials degrade the quality of linearly polarized light coming through the polariscope, causing various colors to show up. With a polariscope, geologists identify certain crystals and mineral structures. Civil engineers examine stresses inside structures made out of transparent plastic, to understand how to build them better. Photonics technicians evaluate the quality of laser glasses and laser crystals with polariscopes.

• Have the room lights turned back on. With the items from your packet, show the students how to make a polariscope in one hand. Ask them to find the colored stripes in the clear sheet of plastic from their packet. [*While looking through the polariscope, they must insert the clear plastic in the polariscope as shown here. It may make a difference whether it is horizontal or vertical*]

• Ask the students to evaluate the internal stresses in the plastic spoon and handle..

• Have everyone put all items back in the packets. Suggest that, once home, the students may demonstrate the magic stripes trick to their families, since they know the secret polarizer code and how to use a polariscope.

2) Introduction and Objective

The ***OPTRICKS Suitcase*** is designed to make it easy to go into a classroom and get young people excited about careers in technology. Kids enjoy the theme packets that may be taken home and shared with others. Every student takes home a flyer (on the back of the Periodic Tables of Elements) which serves as a prompt to aid the young person in describing you, the purpose of your visit, and your demonstrations.

You will want to customize your classroom visit with items and observations based upon your job and work environment. You must decide when and how to insert this information into the presentation. Expect to be asked questions such as: how much money you make, how long you went to school to prepare for your line of work, and what you like (and dislike) most about your job. Interaction with your audience can be exhilarating if you come prepared.

The objective is to convey a sense of excitement about technology in a short period of time. To this end, we have designed a “typical” classroom presentation with some initial demonstrations that should quickly capture the students’ attention. You should then be able to zoom through three activities that illustrate the overall theme of “Colors in White Light”.

After giving dozens of presentations, members of the Rochester & Southern California Sections of the OSA have learned quite a few lessons. The following summarizes a few general observations and suggestions:

- Make arrangements with the teacher ahead of time to have an overhead projector, screen, and table at the front of the room. The table will ensure that you have room enough to spread out.
- We have found that the presentation is most successful when given to the 6th-10th grades. Younger kids are excited by the gifts you bring, but the message seems to get lost.
- Ask the teacher for help in handing out the theme packets and flyers, and for operating the room lights (more on this later).
- It takes a minimum of 40 minutes to do the presentation as described in this guide. With more time, you can slow down the pace, add more personal information, and entertain more questions. With less time, you may want to cover only two activities.
- Adjusting the flow of your presentation is important. Read your audience and move on if their attention seems to be wandering. You have plenty of material.

3) Preparing for a Visit

1 to 2 weeks before a visit

Obtain the following information from the classroom teacher in order to prepare your suitcase and make a take-home flyer:

- School name, school address, teacher's name, classroom location
- Ages of students
- Number of students
  - Take four extra sets of theme packets and flyers (*one for the teacher, one for you, and two spares*)
- Length of presentation
- Number of presentations
  - Will you speak to one or two classes?
- The setting and the teacher's expectations
  - Is your visit part of a career day at school where others are coming in to describe their occupations as well?
  - Is your visit being used to emphasize experiments that demonstrate “fun with science”?
  - Is your visit being used as part of a science unit on the topic of physics?
- Protocol for entering the school
  - You will probably report to the school office for a badge.
- Appropriate arrival time
  - 20 minutes before the target class time?
  - Will there be time available to set-up in the classroom?
- Would the teacher like a short biography to introduce you to the class?

The day before your visit

Check the contents of your suitcase. Print out the flyers, print a transparency of the flyer to use on the overhead projector, and take some time to practice, even if you simply run through the presentation in your mind. If you have a laser pointer, you might bring it along, **but be careful not to share it with anyone or leave it where it can be “borrowed”.**

• Ask everyone to seal the flashlights and peepholes back into the packets. Tell them the packets are theirs to keep. Suggest that they can reveal to family members the secret of seeing colors in white light through diffraction.

9) Magic Stripes - Color by Polarized Transmission (Polariscope)

Remove the slinky from the suitcase and choose a volunteer to come up front.

• Give the student one end of the slinky and ask her (him) to hold this end steady at mid-chest level. Stand 4 feet away and begin to vibrate your end up and down and in a circle. You should be able to create a standing wave with a few nodes, but the plane of vibration should not be well defined.

• State that, in addition to color, light has a wave nature. The slinky represents a light wave. This motion represents unpolarized light – light without a preferred vibration direction. *[For simplicity, we ignore circularly polarized light.]*

• Stop the circular motion and vibrate only vertically. State that light is “polarized” when it vibrates in one direction – vertical or (switch hand motion) horizontal. *[Horizontal motion is a bit harder to maintain while speaking and you might want to go back to the vertical motion.]*

• Define linearly polarized light as light whose vibration direction is in a plane. *[Here you might use the overhead transparency from NASA that shows the spectrum from radio to gamma-rays, with low frequency, long wavelength and high frequency, short wavelength radiation. The photos at the bottom of the transparency show what the Milky Way looks like through different telescopes that “look” at different frequencies or wavelengths of optical radiation.]*

• Put the slinky away.

Have the teacher hand out the Magic Stripes Theme Packet, but ask the students not to open them yet. When everyone has their own packet, proceed as follows:

• Ask the students to remove everything from the packet and place the 4 items on their workspace. (See Figure 7.) Have them check that they have dark piece of plastic (cylinder), one transparent piece of plastic with writing on it, a clear plastic spoon broken in two pieces.

• Take your two large pieces of linear sheet polarizer and hold them up, one in each hand. Combine them about one foot in front of your face with the transmission axes parallel. You should be able to see the

The students need to hold the lenses about 1 inch above the page so that they can see the dots magnified. You may need to help them so be patient. Make sure all the students can see the colored dots before you continue.

- Ask the students what color dots they see. These pages were printed using a color printer that only has Cyan, Magenta, Yellow and Black ink, so those are the only colored dots.
- Looking where there is more white space and less color will make it easier to see the dots.

The students can take these lenses and all the theme packets home with them to share with their family and friends. They can look at all kinds of printed materials with these lenses.

8) Rainbow Peephole™ - Color by Redirecting (Diffraction)

Have the teacher pass out the **Rainbow Peephole™ Theme Packets**, but ask the students **not to open them yet**. When everyone has their own packet, proceed as follows:

- Remove the flashlight and the peephole from your packet, hold them up, and identify them. Ask the students to remove theirs and figure out what to do by referring to the image of the young lady on the back of the packet.

- During the "oohs" and "ahs", ask the group, "Where does the color come from?" [*Many children will answer that the colors comes from the peephole. Tell them that the color comes from the white light in the flashlight.*]

- You can ask any or all of the following questions:
  - Do you see a regular pattern? Describe it.
  - Identify all of the colors. Are they the same in each spot?
  - Does the pattern change if the flashlight is close or far from the peephole? How?
  - Do you see colors from other people's flashlights, even those far away from you?
  - Do you see colors from the room lights?

- Hold up the packet and show the picture on the front. Describe this as a highly magnified photograph of the surface of one side of the clear plastic in the peephole. It is taken with an instrument called an atomic force microscope. [*Optical engineers develop instruments like this.*]

- Note that the scale is in microns, that a human hair is 30 to 80 microns wide, and that the plastic has a regular array of small bumps across it that are only 2 microns high – too small to be seen or felt.

- The bumps are packed so closely together that about fifty of them could fit inside a human hair. These bumps are responsible for redirecting the light coming into the peephole, depending on its color. Point out the similarity between the regular array of bumps and the pattern seen through the peephole.

4) Getting Started (Breaking the Ice)

The teacher or one of the students has just introduced you.
Try this next:

X-Light Demo

- Thank the teacher for inviting you to school, restate who you are, where you work, what you do, and the types of people with whom you work.

- Ask the teacher to turn the lights down. Take out and turn on the X-Light demo. Whirl the X-Light around on the lanyard and wait for the students to calm down. (You may need to calm them down a bit.)

- Ask the students to explain what they are seeing. Call on a few students to answer the question. After a few answers, explain that when the flashing lights are stationary you just see the flashing lights in one place, moving forward in time. When you whirl the flashing lights around, they are moving in both space and in time. Thus we talk about "Space-Time"

- Ask the students if they like colored lights. Tell them we are going to talk about colors and light.

- Put the demo away!

Happy and Unhappy Balls (if time permits)

- Ask a student to come forward to help you.

- Hand her (him) the two black spheres and ask the student to drop both onto the table. [*As explained in the note from Arbor Scientific included in your suitcase, the rubber in one ball is fully vulcanized, retains its shape, and bounces well. The rubber in the second ball is much more easily deformed and does not bounce*.]

- As your helper continues to "bounce" the unhappy ball, ask which kind of rubber would be best suited for the tires of a racing car or the bottoms of a pair of sneakers. [*Ans: a blend of both, to improve friction or gripping power and to absorb shocks, but not too "energy absorbing", because this is accompanied by high heat from friction and excessive wear*.] The best rubber for a handball is ???

- Again, you might point out that technology and invention are the keys to improving our lives.

- Put the demo away!

5) Introduction to Optical Engineering

Now that you have their attention, you are ready to introduce a field of technology called "optical engineering".

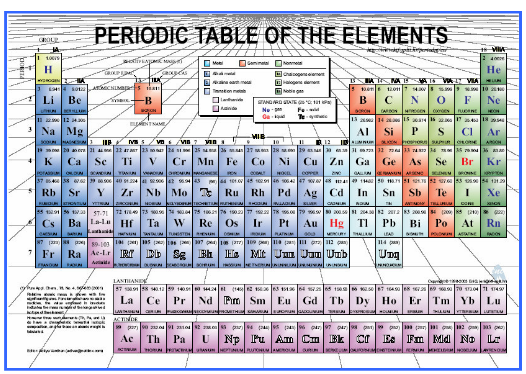
- Hold up the **silicon wafer** (shiny side out) and the **large silica lens**. Ask if anyone can identify them. [*The lens is usually easy. The students will likely refer to the wafer as a mirror.*]

- Identify the wafer as single crystal silicon, a pure elemental substance and the basis for all computers (the chips and microcircuits). Show them the reverse side of the wafer which is dull, and explain that this side is ground and the other is polished to a mirror surface. Some optical engineers develop the technologies for turning rough silicon wafers into integrated circuits for making computer chips.
  [*You may want to elaborate on this.*]

- **Hand out copies of the periodic table of elements** *(useful for 8-9th grades and higher)* and use the transparency to help the students locate silicon (#14) and oxygen (#8).

- State that the periodic table is a visual means for displaying all of the elements known to man – every bit of matter in the universe is composed of one or more of these elements. Physicists, chemists, materials scientists, geologists, and optical engineers work with many of these elements and the compounds they form.

- Explain that the only difference between the silicon wafer and the silica lens is oxygen. Point out how a little oxygen turns a visibly *opaque* material into a visibly *clear* one. Suggest that if we were aliens whose vision was in the infrared, the silica lens would look opaque and the silicon wafer would look transparent! Mention that optical engineers build lenses into systems that image light, such as the Hubble Space Telescope, the Chandra X-Ray Telescope, or the new digital cameras that record images on silicon.



You can use the two silica lenses to show how a telescope is made by holding them up together.

This can be demonstrated with the two Fresnel lenses as they have different focal lengths. Let the students look at each other through the Fresnel lenses if time permits.

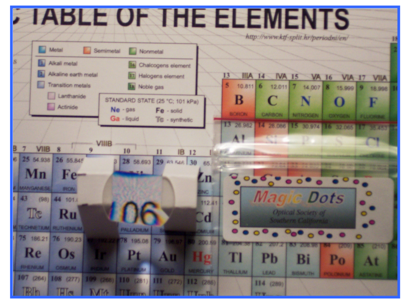
6) Colors in White Light

You are now ready to do some experiments with the class that illustrate some of what optical engineering is all about.

- State that these experiments explore several ways to "see" the colors in white light. You are prepared to reveal certain "secrets" that might not be obvious to others when doing these experiments. [*The "trick" aspect to these demos works well with 6th graders!*]

- Mention that many people with technical degrees in optical engineering, Photonics, physics, electronics, computer engineering and mechanical engineering work in companies and laboratories throughout Southern California and use optics and Photonics to make many different products and do research in many different fields.

Magic Dots



lenses

Magic Stripes

polarization

Magic Patch

selective reflection

Rainbow Peephole™

diffraction

7) Magic Dots – The Printing Experience

Have the teacher pass out the lenses and ask the students to use them to look at the colors on the Periodic Table.