Rapid Vitamin D Enhancement in Mushrooms Using Pulsed UV Light

51st Annual Penn State Mushroom Industry Conference
Sept 20-22, 2009

XENON

Lou Panico, CEO

Presentation Overview

- The Nutritional Value of Vitamin D
- Mushroom Vitamin D Research
- Understanding Pulsed UV Light
- Future Pulsed Light Advances
- Acknowledgements

Vitamin D – the "Nutrient of the Decade?"

- **Vitamin D, known as the "sunshine vitamin"**
- **Vitamin D has been found to:**
  - **Strengthen bones**
  - **Reduce tumor growth**
  - **Lower your risk of cancer**
  - **Reduce your risk of multiple sclerosis**
  - **Lower your risk of diabetes**
- **New studies continue to highlight vitamin D benefits**

Study identifies vitamin D's benefits for diabetic heart health
Nutra Ingrediants.com; Stephen Daniells, 24-Aug-2009

Is there a health problem?

Low consumption of vitamin D is a concern

Breaking News on Supplements & Nutrition - North America

Be aware of vitamin D insufficiency, says US Dermatology Academy

By Lorraine Heller, 16-Jul-2009

This situation creates the opportunity to increase consumption of mushrooms Worldwide

Mushrooms as a Source of Vitamin D

- **Mushrooms are the only non-animal food that can provide Vitamin D**
  - **Cultivated mushrooms unexposed to UV light do not provide vitamin D**
  - **Mushrooms have relatively high levels of ergosterol - when exposed to UV light is converted to ergocalciferol (known as vitamin D_2)**
- **A study performed by the United States Department of Agriculture demonstrated how continuous UV exposure can accelerate vitamin D in mushrooms – achieving levels > 100% DV in 8 minutes of exposure time.**
- **A study performed by The Pennsylvania State University, using pulsed UV light, demonstrated that vitamin D can be increased >100% DV in under 1 second.**

Products on the market

Monterey Mushrooms touts vitamin D benefits

Published on 01/07/2009 (The Packer)

“We’re challenging people to get more vitamin D and get their levels up,” said vice president of biotech and product development John Kidder.

Products on the market

Dole Mushrooms pack a vitamin D boost

Published on 05/28/2008 (The Packer)

“To boost the natural value of vitamin D in the mushrooms, the company exposes them to an intense burst of light similar to that of a camera flash for less than a second, said Gary Schroeder, director of Dole Mushrooms and president of Oakshire Mushroom Farm Inc., Kennett Square, Pa., which supplies Dole-brand mushrooms.”

Can Vitamin D Mushrooms Create Consumer Interest?

Consider what Good Housekeeping magazine has to say!

First Annual VIP (Very Innovative Products) Awards

Thousands of products are reviewed in GHRI's labs each year. Many are problem-solving. Many perform well. And quite a few are innovative. But the winners of GH's First Annual VIP (Very Innovative Products) Awards meet *all three criteria.*

Portobello Mushrooms

Most of us don't get enough vitamin D — a real concern, because low levels are linked to cancer, heart disease, high blood pressure, and diabetes. What's more, very few foods provide much of the nutrient. Enter Dole's Portobello mushroom caps and slices: One package contains 800 IUs of D, the daily amount experts suggest. The secret is a simple flash of light during the growth process, which helps the mushrooms synthesize more D, without changing the taste. *$3.50 for six ounces, Dole; major supermarkets*

How did the mushroom industry get to this point?

There has been a growing number of research studies investigating how ultraviolet treatment of fresh mushrooms increases vitamin D2

Light-zapped mushrooms filled with vitamin D

Bringing 'shrooms out of the dark packs them with sunshine nutrient

Associated Press

Tues., April 18, 2006

Research Studies –
Mushroom + UV Exposure = Vitamin D

- Mau, J. L., Chen, P. R., & Yang, J. H. (1998). Ultraviolet irradiation increased vitamin D2 content in edible mushrooms. Journal of Agricultural and Food Chemistry, 46, 5269-5272
- Jasinghe, V. J., Perera, C. O. (2005). Distribution of ergosterol in different tissues of mushrooms and its effect on the conversion of ergosterol to vitamin D2 in edible mushrooms. Food Chem. 92, 541-546.
- Jasinghe, V. J., Perera, C. O. (2006). Ultraviolet irradiation: The generator of Vitamin D2 in edible mushrooms, Food Chemistry, 95, 638-643
- Feeney, M.J., Optimizing Vitamin D2 in mushrooms, (2006). Pilot study to expose mushrooms to ultraviolet light. Mushroom News 54(5):2-24
- Xin, H., Mannen, A., (2008). Commercialization of Vitamin D Enhanced Mushrooms by UVB Light Treatment. Mushrooms Canada, Guelph Food Technology Centre
- Roberts, J. S., Teichert, A., McHugh, T. H.. (2008). Journal of Agriculture and Food Science, *Vitamin D_2 Formation From Post-Harvest UV-B Treatment of Mushrooms (Agaricus bisporus) and Retention During Storage*
- Beelman, R. (2008). Mushroom Short Course; *Mushroom Nutritional Research*; Dr. Robert Beelman Professor of Food Science, The Pennsylvania State University
- Beelman, R.B. and Kalaras, M.D. (2008). Vitamin D2 Enrichment In Fresh Mushrooms Using Pulsed UV Light
- Williams, R. (2009). Installing a Vitamin D System for Pulsed Light Treatment of Mushrooms; Xenon Corporation
- Koyyalamudi, S. R.; Jeong, S. C.; Song, K.Y.C., Pang, G (2009). Vitamin D2 Formation and Bioavailability from Agaricus bisporus Button Mushrooms Treated with Ultraviolet Irradiation. J. Agric. Food Chem., 57, 3351-3355

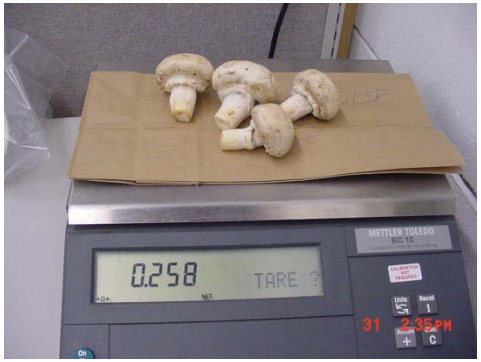
Focus of research

- What amount of vitamin D increase is achieved?
- Does the UV intensity influence the level of vitamin D?
- Is there a reduction in vitamin D during an 8-day shelf life?
- Does the color of the mushroom change?
- Is there any difference when mushrooms are washed or sliced?
- What is the added cost to treat mushrooms in a commercial installation?
- Is there a temperature rise during exposure?
- Can different types of mushrooms be treated?
- Is there any difference in vitamin D levels for different mushrooms?

UV Delivery Methods

- Initial studies done with mercury UV-B lamps
- Increasing number of studies being done with xenon pulsed UV light lamps
  - **Penn State -USA (studies in 2008 and 2009)**
  - **Xenon Corp (study in 2008)**
  - **Mushroom Growers (2008 – 2009)**
  - **Australian Mushroom Growers Association (2009)**

Pulsed UV Light Treatment of Mushrooms at Xenon Corp



																RDI =	400		% of
	System: RC-742 with 16" lamp housing and Steri Chamber																	% of	your
	By: R.Williams								J / CM^2	J / CM^2	J / CM^2	J / CM^2					IU of	your	daily
		Inches		Electrical				BB	BB	Act - 5	Act - 5		IU / 100g	IU/100g	IU / 100g	Vitamin	daily	require-
Weight	Temper-	Diameter	Orientation	Energy	Number	Distance	Lamp	Energy	Energy	Sed 240	Sed 240	IU / 100g	/ pulse	/ control	/ pulse	D	require-	ment
Lbs	ature	of		/ pulse	of pulses	inches	Type	read / pulse	Integrated	Read / pulse	Integrated			Portobello	B VS C	/mushroom	ment	per mushroom
	Deg F	Mushroom																
0.341	78	5.03	Top Up	505 Joules	1	1.25"	C	1.12	1.12	0.0319	0.0319	184	184	9.2	1.511	284.6	71.2%	71.2%
0.319	79	5.26	Top Up	505 Joules	2	1.25"	C	1.12	2.24	0.0319	0.0638	383	191.5	19.15	1.452	554.2	138.5%	138.5%
0.269	79	4.85	Top Up	505 Joules	3	1.25"	C	1.12	3.36	0.0319	0.0957	374	125	18.7	2.230	456.3	114.1%	114.1%
0.286	78	4.79	Top Up	505 Joules	2	1.25"	B	0.873	1.746	0.0343	0.0686	556	278	27.8	1.000	721.3	180.3%	180.3%
0.335	79	4.9	N/A	N/A	0	N/A	N/A	0	0	0	0	20	N/A	1		30.4	7.6%	7.6%
		Inches		Electrical				BB		Act - 5			IU / 100g	IU/100g	IU / 100g			
Weight	Temper-	Diameter	Orientation	Energy	Number	Distance	Lamp	Energy		Sed 240		IU / 100g	/ pulse	/ control	/ pulse			
Lbs	ature	of		/ pulse	of pulses	inches	Type	read / pulse		Read / pulse				Portobello	B VS C			
	Deg F	Mushroom																
0.24	71	2.2	Top Up	505 Joules	1	1.25"	C	1.12	1.12	0.0319	0.0319	674	674	33.7	1.0460	733.7	183.4%	45.9%
0.278	70	2.3	Top Up	505 Joules	2	1.25"	C	1.12	2.24	0.0319	0.0638	1670	835	83.5	0.8443	2105.8	526.5%	131.6%
0.268	71	2.17	Top Up	505 Joules	3	1.25"	C	1.12	3.36	0.0319	0.0957	1770	590	88.5	1.1949	2151.6	537.9%	134.5%
0.241	71	2.12	Top Up	505 Joules	2	1.25"	B	0.873	1.746	0.0343	0.0686	1410	705	70.5	1.0000	1541.3	385.3%	96.3%
0.228	70	2.11	N/A	N/A	0	N/A	N/A	0	0	0	0	20	N/A	1		20.7	5.2%	1.3%

mushroom to window of housing.
lion Labs
n part number 890-1958
non part number 890-1957
w for each sample

Study on Portobello and White Mushrooms using Pulsed Light

Results from tests performed at Xenon Corp's lab in Wilmington, MA

No Exposure - control	IU	% DV
Portabella control	*30*	*8%*
Sliced White Whole control	*20*	*5%*
Portabella		
1-pulse	*285*	*71%*
2-pulses	*554*	*139%*
3-pulses	*456*	*114%*
Sliced White Whole		
1-pulse	*734*	*183%*
2-pulses	*2106*	*526%*
3-pulses	*2151*	*538%*

As few as 2-pulses, applied in less than 1-second produced vitamin D >100% DV in fresh mushrooms

Study on White Button, Brown Button, Shiitake and Oyster Mushrooms

Results from tests performed at Penn State, Dept of Food Science

%Daily Value* Vitamin D_2 In One Serving (84g)					
MUSHROOM TYPE	Number of Pulses				
	0	1	2	3	4
White Button (Agaricus bisporus)	0%	325%	562%	724%	824%
Brown Button (Agaricus bisporus)	4%	362%	522%	746%	899%
Shiitake (Lentinula edodes)	3%	490%	867%	1200%	
Oyster (Pleurotus ostreatus)	15%	651%	1129%	1618%	

Notes

1 - *100% Daily Value (DV) = 400 IU

2 - Pulse rate = 3 pulses/second; Xenon Corp "B" Lamp; 505 Joules/pulse

3 - Mushroom top placed 1.25" below quartz window, 16" Lamp Housing

4 - Study performed by M. Kalaras and R. Beelman, Dept of Food Science, Penn State University

1-pulse, applied in under 1-sec increased vitamin D_2 to over 100% DV in one serving fresh mushrooms

Pulsed UV Light Equipment

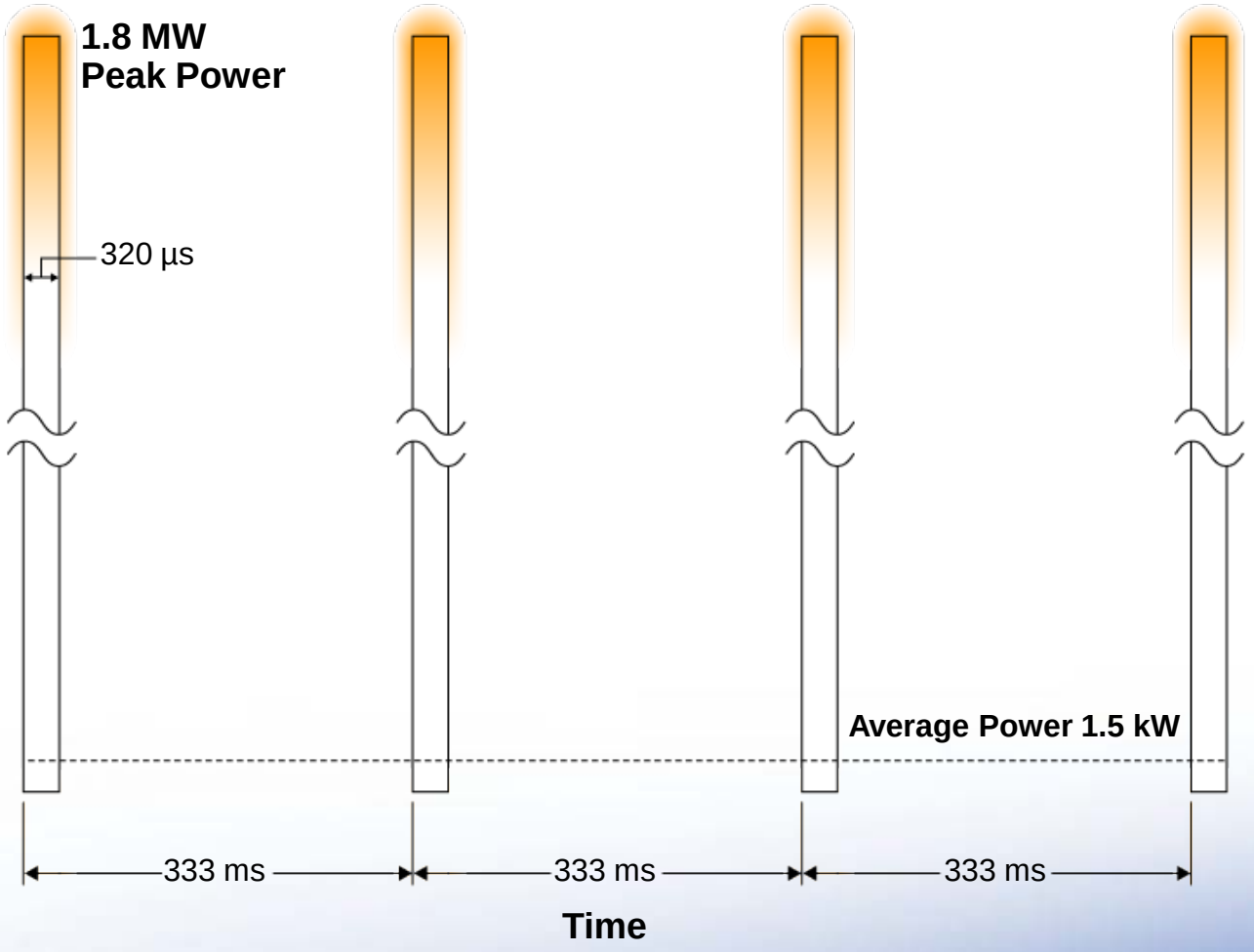
Lamp Housing with Flashlamp

Controller

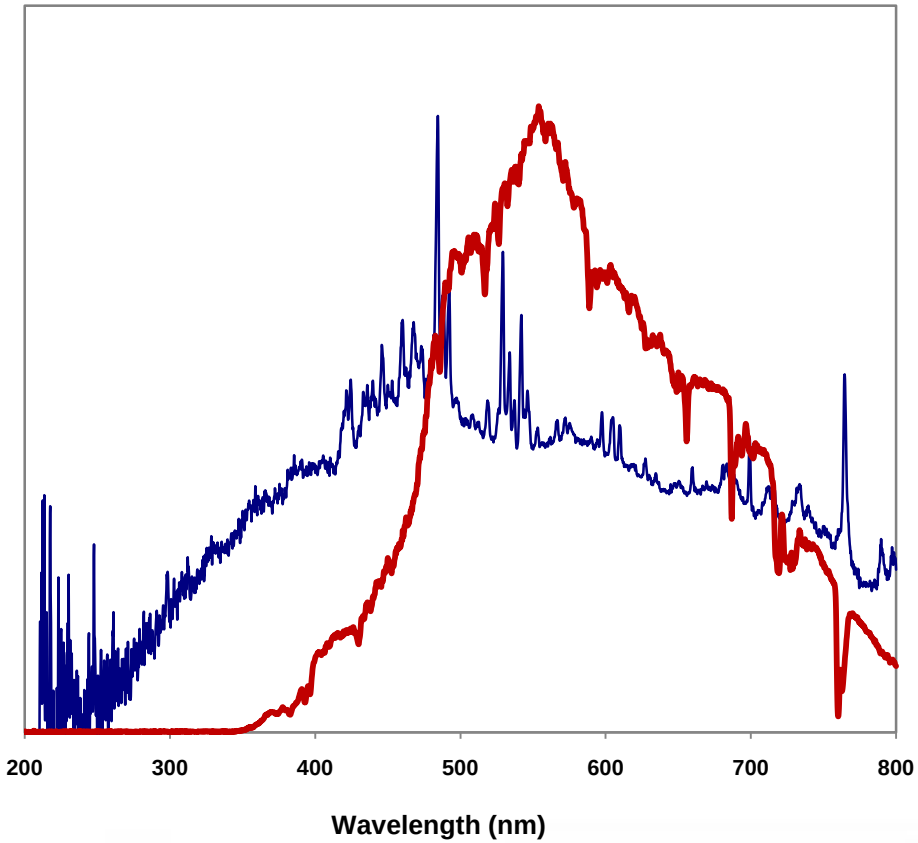
Lamp Housing Blower

The Basics of Pulsed Light
High Peak Power Low Average Power

Peak vs. Average Power



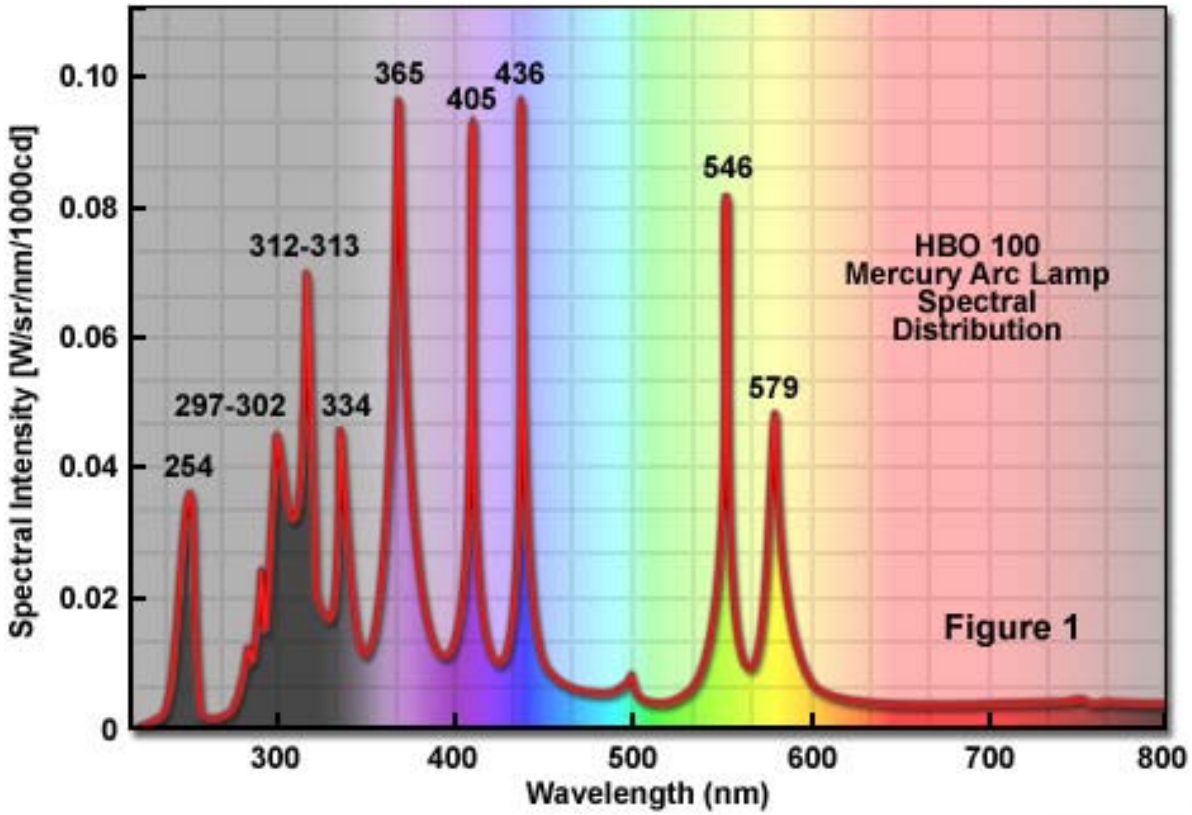
Spectra
– Sunlight vs. Pulsed Light Lamp



Blue = xenon *Pulsed Light lamp* **Red** = *Sunlight*

Pulsed light more closely matches the spectrum of natural sunlight

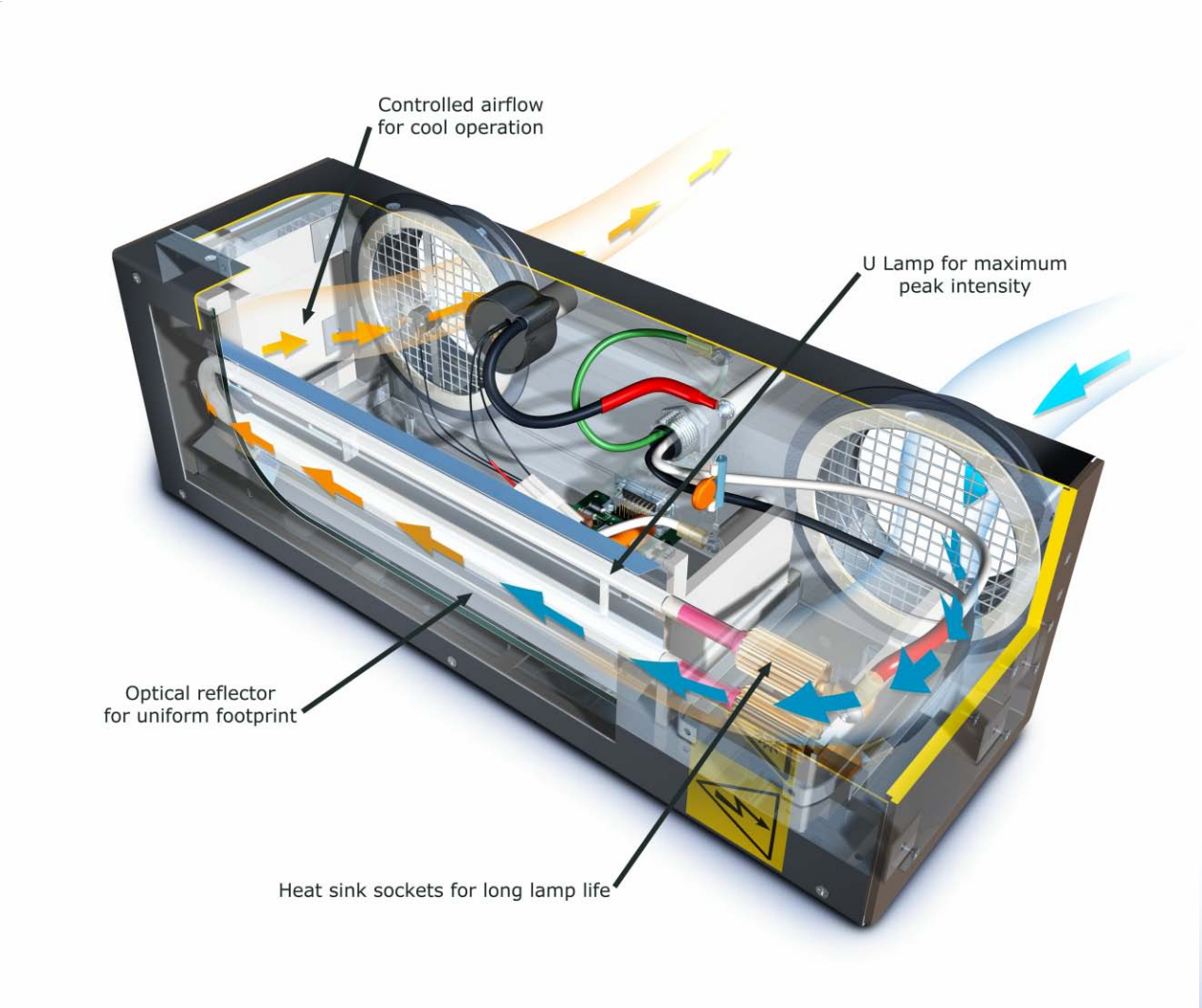
UV-B (Mercury) Lamp
- ‘line’ spectra



Zeiss-Campus, Fundamentals of Mercury Arc Lamps

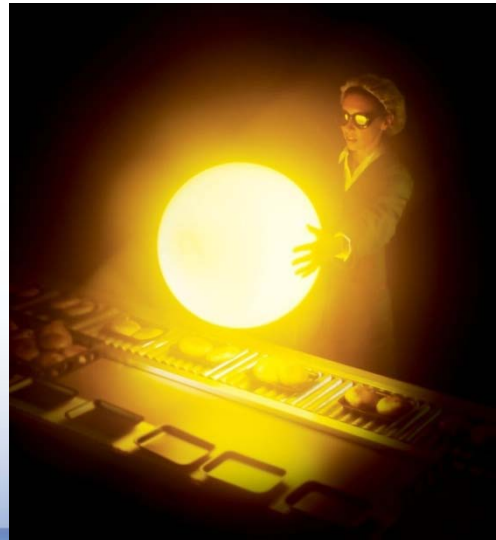
Mercury Arc Lamp Spectra is not continuous like the Sun spectra

The Heart of a Pulsed Light System



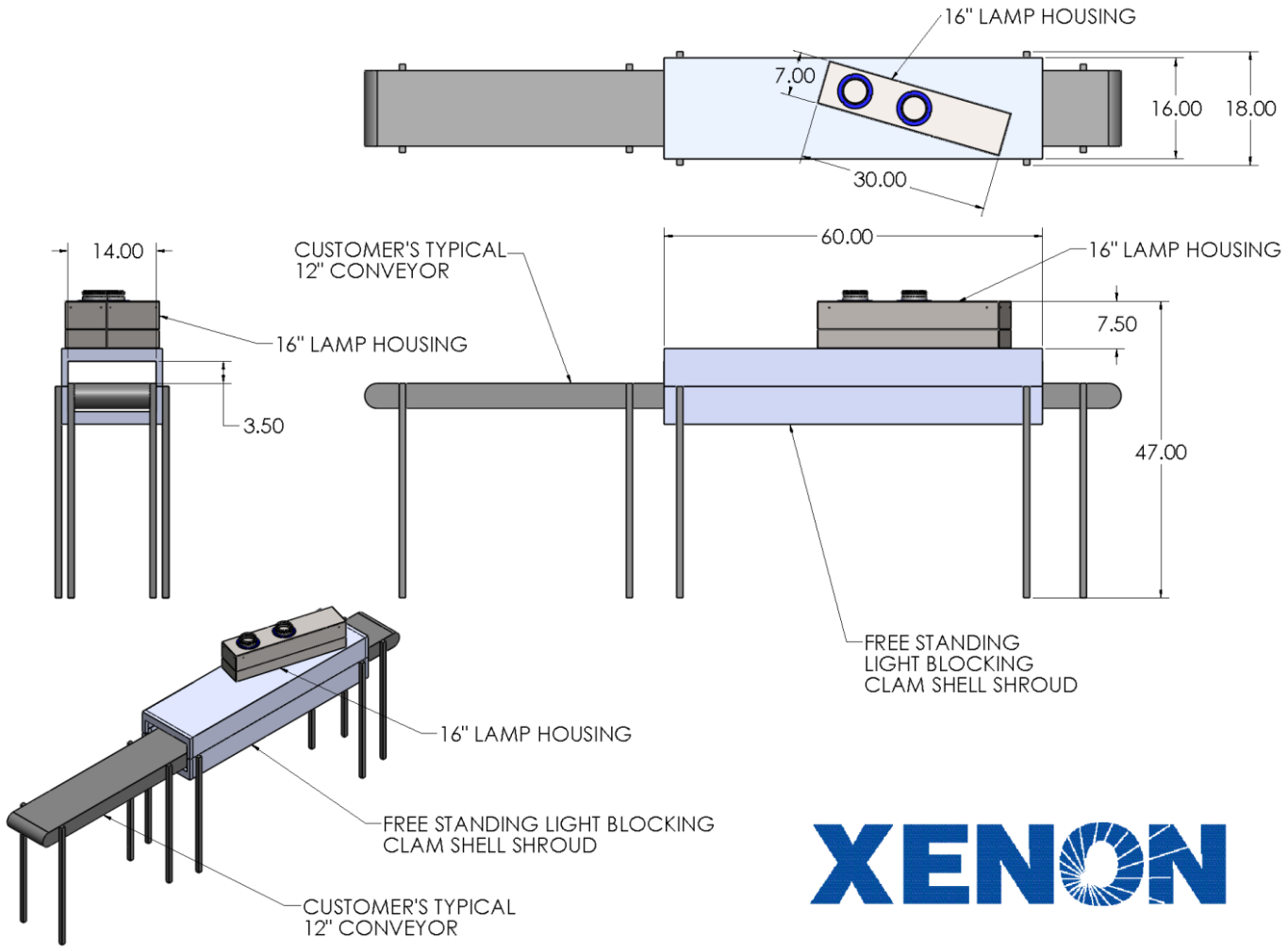
Integrating Pulsed Light into an Inline Processing system

- **Step 1** – Review installation guidelines[1] with Xenon
- **Step 2** – Design a light blocking tunnel to fit over mushroom conveyor belt
  - Pulsed light is very bright – must be shielded from operator eyes
  - We can recommend experienced integrator to help but have found most growers can do this work
- **Step 3** – Confirm actual vitamin D level
- **Step 4** – Establish routine verification and maintenance schedules



[1] Williams, R. (2009). Installing a Vitamin D System for Pulsed Light Treatment of Mushrooms; Xenon Corporation

Designing Light Blocking Tunnel Over Conveyor Belt



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Variables that control the level of vitamin D delivered

- Variety of mushroom
  - oyster, portabella, white button, shiitake...
- Mushroom size
- Position below lamp housing window
- Position of lamp housing over conveyor
- Speed of conveyor belt

Designing a system using Pulsed UV Light system, can address all variables and result in a reliable, repeatable, inline process at grower facilities.

Pulsed UV Lamp vs. Mercury Lamp – for vitamin D enhancement

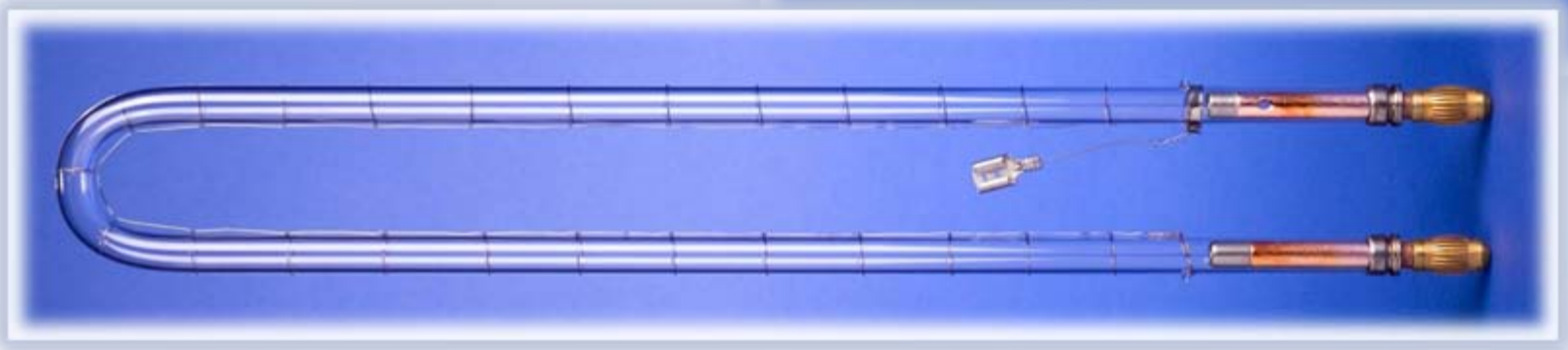
	Pulsed Light System	Mercury Lamp System
Spectra	Close to Sunlight	Line Spectra
Heat	Minimal IR	Significant IR
Personnel Safety	Risk Eliminated	Mercury (Hg)
Environmentally Friendly	No Hg & Less Energy	Hg and More Energy

Future Advances
Longer lamps

Increase the optical footprint
16-inch lamp > 30-inch lamp > ?

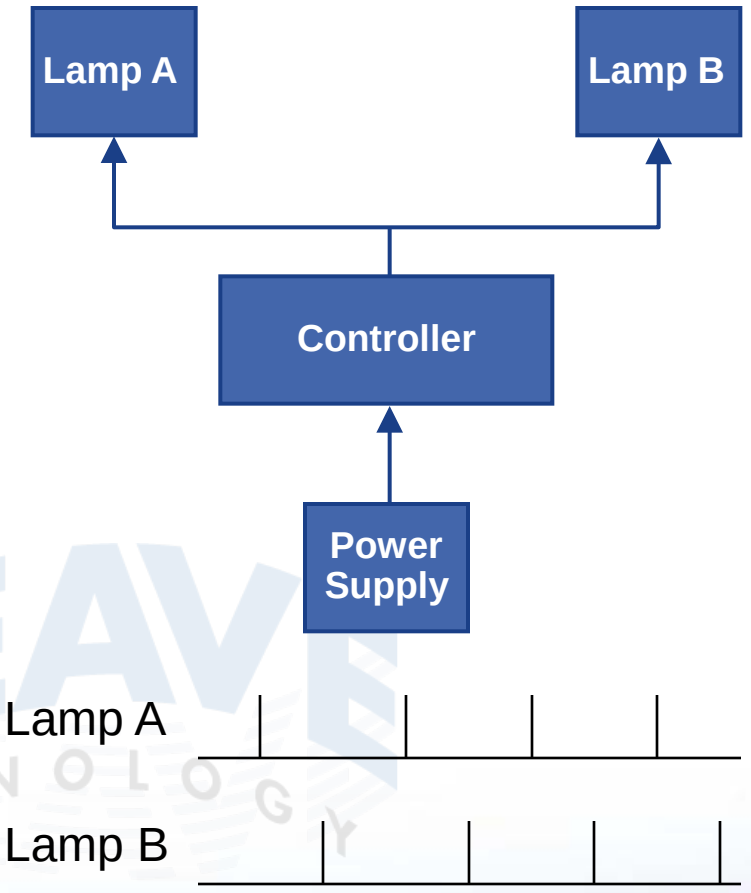
Future Advances
New Lamps and Optical Designs

U-lamp widens
the optical footprint



Future Advances
InterWeave™ Technology

- Less hardware
  - Less cost
- Simplified controls
- Handle multiple conveyor lines
- Increased mushroom output



Acknowledgements

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- Mushroom Growers Worldwide
  - USA
  - Canada
  - South America
  - Mexico
  - Ireland

Questions & Comments

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